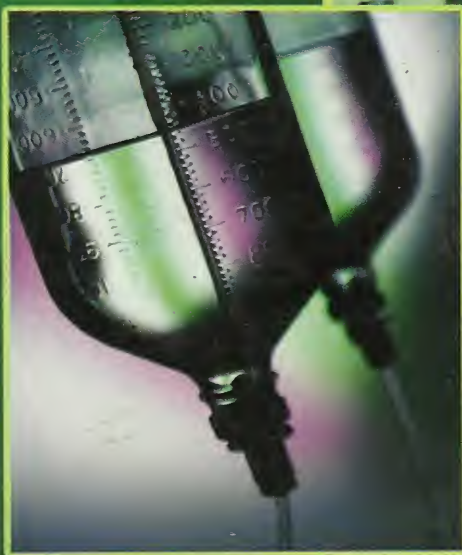


A review book

FLASHLIGHTS ON

ANESTHESIA



Hesham M EL-Azzazi

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ANESTHESIA

FIRST EDITION

HESHAM M EL-AZZAZI, MD

Lecturer of Anesthesia and Intensive Care
Faculty of Medicine
Ain Shams University

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17 B El-Obour Building, Salah Salim Street, Cairo, Egypt.

Or heshamelazzazi@hotmail.com

(002) 012 7378686

THIS WORK IS DEDICATED TO

MY PARENTS, MY WIFE & MY CHILDREN, AHMED & HANA.

Preface

There is only so much time and effort that can be allocated to learning anesthesia. This book attempts to provide all the basic knowledge that meets the needs of medical students and young doctors training in anesthesia. I have tried to exclude details that have neither clinical application nor value to practicing anesthesiologists.

The text is kept simple in order that it may more easily become part of long term memory and automatic response.

I sincerely hope that your reading of this book may not only prove profitable to you, but will stimulate your permanent interest in the field of anesthesia as well as provide the basic knowledge essential to establish a good and solid base on which future knowledge can be added.

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CHAPTER 1

THE HISTORY OF ANESTHESIA

In Ancient Times

A-General Anesthesia:

The ancient **Egyptians** used the combination of opium poppy (morphine) and hyoscyamus (hyoscyamine and scopolamine) ; a similar combination , morphine and scopolamine , is still used parenterally for premedication.

B-Regional Anesthesia:

In ancient times, it consisted of compression of nerve trunks (nerve ischemia) or the application of coldness (cryoanalgesia).

The Term “ANESTHESIA”

- The Greek philosopher **DIOSCORIDES** is said to have first used the term anesthesia in the first century AD to describe the narcotic-like effects of the plant mandragora (An =no, Asthesia = sensation).
- The present use of the term to denote the sleeplike state that makes possible painless surgery is credited to **OLIVER WENDELL HOLMES** in 1846.

Anesthesia Practice in Arabic- Islamic Medicine

- **Ibn Al Koff** (1232-1286 AD) wrote a complete chapter on pain relief in his book ‘**Al Omdah Fi Sinaat Al Jirahah**’. He differentiated between true and non-true pain relief considering non-true pain relief the ‘Anesthetic’ which the surgeon may use for treatment of pain or to be able to institute the surgical treatment.
- The technique of use of ‘**Soporific Sponge**’ is purely Arabic and was not known before. The ‘**Soporific Sponge**’ was put in juice of hashish, papver, and hyocymine, and then dried under the sun. When called upon for use, it was humidified again, and placed at the patient’s nose, so that the mucus membrane absorbs it (it is presumed to cause deep sleep and relief of surgical pains). The discovery was introduced into Europe and was practiced until the 18th century when modern inhalational anesthetics were introduced in the 40s of the 19th century.

Important Names In Anesthesia:

1- JOHN SNOW: (1813-1858), British.

- He is generally considered **the father of anesthesia**, as he made the art of anesthesia a science.
- He was the 1st physician to be a full time anesthetist.
- He described the physiology of general anesthesia and the 5 stages of anesthesia as he was interested in ether.
- In 1847, he published **the 1st book on general anesthesia**, "On the Inhaler of Ether".
- In 1853, he acted as an anesthetist at the birth of Queen Victoria’s eighth child, Prince Leopold and again in 1857, at the birth of Princess Beatrice.
- In 1858, he published his 2nd book, "On Chloroform And Other Anaesthetics".



Figure 1-1 Artist impression on how 'anesthetic sponge' (inhalaional anesthesia) was used by a surgeon in Arabic-Islamic medicine (quoted from Al-Bakri et al., 1999).

2- JOSEPH T. CLOVER: (1825-1882), British.

- He took Snow's place after snow's death as England's leading physician anesthetist.
- He emphasized continuously monitoring the **patient's pulse** during anesthesia, a practice that was not widely accepted at that time.
- He was the 1st to use the **jaw-thrust** maneuver for airway obstruction.
- He was the 1st to have **resuscitation equipment** always available during anesthesia.
- He was the 1st to use a **cricothyroid cannula** (to save a patient with an oral tumor who developed complete airway obstruction).

3- HEINRICH FRIEDRICH WILHELM BRAUN: (1862-1934), German.

- He is called **the father of local analgesia**.

As • in 1902, he was the 1st to add epinephrine to prolong the action of local anesthetics.

- in 1905, he was the 1st to use procaine as a local anesthetic and he published the 1st edition of the textbook "**Local Anaesthesia**".

4- ARTHUR E. GUEDEL: (1883-1956), American.

- He was the 1st to elaborate on the signs of general anesthesia after Snow's original description.
- He made an early description of **self-administration of N₂O and air** for obstetrics and minor surgery.
- He advocated cuffed endotracheal tubes.
- He introduced **artificial respiration** during ether anesthesia in 1934.

CHAPTER 2

THE PRACTICE CONDUCT OF ANESTHESIA

Anesthesia is a mixture of both science and art.

Balanced anesthesia

The concept of balanced anesthesia was introduced by **John Lundy** in 1926.

It consisted of:

- | | | |
|----------------------|---|--|
| 1- Narcosis | by anesthetic agents | i.e. loss of consciousness. |
| 2- Amnesia | by N ₂ O (replaced now by midazolam) | i.e. loss of memory. |
| 3- Analgesia | by narcotics | i.e. loss of pain sensation. |
| 4- Relaxation | by muscle relaxant | i.e. loss of muscle tone and activity. |

So, the combination of these drugs;

- Decreases the dose of each and so decreases side effects.
- Allows the control of each item independently.

Anesthetic Management

It consists of:

- 1- Preoperative management.
- 2- Intraoperative management.
- 3- Postoperative management.

Preoperative Management

Preoperative visit: It is very important.

- If it is not performed by the anesthesiologist, it is considered negligence if anesthetic morbidity or mortality occurs subsequently.
- All data must be written in the preoperative note.

A- Establishment of Rapport (Doctor-Patient Relationship):

- The patient can discuss with the anesthesiologist the possible causes of anxiety regarding the anesthetic and surgical management.
- The anesthesiologist can explain in simple terms the method of anesthesia, the proposed scope of surgery, the informed consent and the postoperative pain relief.

B- The Preoperative History: (including a review of medical records)

It includes:

1- **Current medical problem and other known problems.**

2- **Special Habits:**

a- **Smoking:**

- Effects:

1- **Vascular:** peripheral, coronary and cerebral vascular diseases.

2- **Respiratory:** carcinoma of lung, COPD, impaired ciliary function.

3- **C.V.S:** nicotine stimulates the sympathetic system causing an increase in HR and ABP and coronary spasm.

4- **Hemoglobin:** cigarette smoke contains carbon monoxide which increases carboxy-Hb. In heavy smokers carboxy-Hb is about 10 %. It decreases the available O₂ by \approx 25%. The t_{1/2} of carboxy-Hb is short (4-6 hours), so its withdrawal for 12 hours can increase the arterial O₂ content.

5- **Immunity:** It alters the **immune system**.

6- **Liver:** nicotine is a hepatic enzyme inducer, so it may affect the perioperative analgesic need.

So; preoperative cessation of smoking is helpful.

b- Alcohol intake:

• **Acute intoxication** enhances the effects of sedatives, opioids and anesthetics so; **decrease the dose of anesthetic drugs.**

• **Chronic alcoholism** induces tolerance to the effects of these drugs due to enzyme induction so; **increase the dose of anesthetic drugs.**

c- **Addiction drugs** as marijuana, cocaine and heroin.

3- Medication history for

a- **Drug allergy and intolerance.**

b- **Drug interactions with anesthetics**

Type	Examples
A- Pharmaceutical Drug interaction occurring outside the body e.g. mixed in the same syringe or infusion bag.	1- Thiopental + suxamethonium → inactivate suxamethonium. 2- Thiopental (alkaline) + atracurium (acidic) → inactivation (precipitate is formed). 3- Sevoflurane + soda lime → hydrolysis to toxic compounds. 4- Insulin or nitroglycerine bind to the polyvinyl chloride used for the standard i.v. tubing → less drug is delivered to the patient.
B-Pharmacokinetic <u>1- At the site of absorption:</u>	1- Iron + antacids → ↓ iron absorption. 2- Anticholinergics and opioids decrease GIT motility → ↑ drugs absorption. 3- Metoclopramide increases GIT motility (i.e. prokinetic drug) → ↓ drug absorption.
<u>2- At transit and storage site:</u> a- Competition for plasma protein binding sites. b- Drugs interact directly with each other in the plasma or tissues.	1- Aspirin, phenylbutazone, or indomethacin → displace warfarin. 1- Heparin and protamine → inactivation.
<u>3- At the site of metabolism:</u> a- Enzyme induction i.e. it ↑ the metabolism of other drugs → ↓ their effect	1- Phenobarbitone, rifampicin, steroids, and phenytoin → ↑ metabolism of warfarin (↑ coagulation), oral contraceptive pills (can cause pregnancy), halothane (can cause severe halothane hepatitis), and isoflurane and enflurane (can ↑ the peak of fluoride level in plasma). 2- Chronic alcoholism or smoking → ↑ i.v. anesthetic metabolism, so ↓ their effect.

THE PRACTICE CONDUCT OF ANESTHESIA

<p>b- Enzyme inhibition i.e. it ↓ the metabolism of other drugs → ↑ effect</p>	<p>1- Chloramphenicol, erythromycin, isoniazid, Ca^{++} channel blockers, ketoconazole and cimetidine → ↓ metabolism of warfarin, phenytoin, oral hypoglycemics, and β blockers. 2- Drugs metabolized by plasma cholinesterases (e.g. etomidate, methotrexate, cyclophosphamide, ester local anesthetics, mivacurium, or MAOIs) → ↓ plasma cholinesterases availability → ↑ suxamethonium action. 3- Anticholinesterases inhibit plasma cholinesterases → ↑ suxamethonium action.</p>
<p>4- <u>At the site of excretion:</u></p>	<p>1- Alkalinization of urine → ↑ excretion of acidic drugs (aspirin, barbiturate toxicity). 2- Acidification of urine → ↑ excretion of alkaline drugs (pethidine, amphetamine toxicity).</p>
<p>C- Pharmacodynamic At site of action (e.g. receptor) or nearby <u>1- Synergistic:</u> it is either: ● Summation or additive effect i.e. $1+1=2$ (Drugs have the same mechanism of action). ● Potentiation (supra-additive), the combined action is more powerful i.e. $1+1=3$ (Drugs have different mechanisms of action).</p>	<p>1- Opioids , benzodiazepines , N_2O, sympatholytics (methyl dopa, reserpine, clonidine), chronic amphetamine, barbiturates, ketamine, local anesthetics (except cocaine), acute alcohol toxicity, or lithium + volatiles → ↓ MAC. 2- Aminoglycosides, volatiles, antiarrhythmics (quinidine, lidocaine, Ca^{++} channel blockers, procainamide), local anesthetics, or Mg sulfate + muscle relaxant → ↑ relaxation. 3- Adrenaline + volatiles → ↑ arrhythmias of both. 4- β blockers and Ca^{++} channel blockers → ↑ depressant effect of anesthetics → ↓ MAC. 5- Tricyclic antidepressant drugs (they block the reuptake of norepinephrine, serotonin, or dopamine at the presynaptic nerve ending) + Opioids especially meperidine → ↑ analgesia and respiratory depression. + Sympathomimetics → ↑ effect of direct acting drugs (e.g. hypertension) so they are avoided with epinephrine containing LAs, pancuronium, and ketamine. 6- MAOIs (they irreversibly inhibit monoamine oxidase therefore, they prevent deamination of tyramine, serotonin, norepinephrine, and dopamine). They should be discontinued 2-3 weeks before surgery. + Opioids especially meperidine → excitatory syndrome (agitation, fits, coma), hypertensive crisis, respiratory depression, and death. + Sympathomimetics → ↑ effect of indirect (mainly) and direct acting drugs so, they are avoided with epinephrine containing LAs, pancuronium, and ketamine.</p>
<p>2- <u>Antagonism:</u></p>	<p>1- β agonists + β blockers. 2- α agonists + α blockers. 3- Morphine + naloxone. 4- Benzodiazepines + flumazenil. 5- Muscle relaxant + prostigmine. 6- Sympathomimetics (ephedrine), acute amphetamine, chronic alcoholism or cocaine + volatiles → ↑ MAC</p>

N.B.; α agonist + β blockers interaction

- Accidental overdose of phenylephrine or epinephrine (e.g. epinephrine containing LAs) in patients receiving long term β blockers can cause congestive heart failure, pulmonary edema and cardiac arrest.

The same occurs if an overdose of phenylephrine or epinephrine is treated by β blockers.

- Because an overdose of phenylephrine or epinephrine causes;
 - Severe α agonist action i.e. VC (hypertension).
 - β_1 activation i.e. tachycardia.

This is accompanied by β_2 activation i.e. peripheral VD.

With β blockers (either as a concomitant treatment or as a treatment of the overdosage), β receptor blockade occurs causing unopposed α action. The latter causes severe VC which leads to irreversible congestive heart failure, pulmonary edema and cardiac arrest.

- Therefore, treatment of overdosage of phenylephrine or epinephrine is best done by;
 - a- If mild to moderate hypertension occurs, it is left untreated as it is transient.
 - b- If severe hypertension (can cause end organ damage especially myocardial ischemia) occurs, it is treated by
 - α antagonists as phentolamine.
 - Direct vasodilators as nitroprusside.

4- History of previous anesthesia, surgery and obstetric deliveries:

To detect previous anesthetic problems e.g. succinylcholine apnea, halothane exposure within 6 months.

5- Family history:

To detect hereditary and pharmacologic conditions associated with anesthesia e.g. porphria, malignant hyperthermia, hypercholesteremia, hemophilia, cholinesterase abnormalities, myasthenia gravis.

6- Review of organ systems:

- General (including the activity level).
 - Gastrointestinal.
 - Hematologic.
 - Orthopedic.
 - Possibility of pregnancy as pregnancy is a contraindication to elective surgery because
 - In early pregnancy → teratogenic (at least theoretically) effects.
 - In late pregnancy → induce spontaneous abortion.
 - In late pregnancy → increased risk of aspiration.
- | | |
|--------------------------------|-------------------|
| - Respiratory. | - Cardiovascular. |
| - Endocrinal. | - Nervous. |
| - Psychiatric. | - Renal. |
| - Infection as AIDS, hepatitis | |

7- Last oral intake.

N.B.; - If there is any trauma, search for other trauma.

- If there is any congenital anomaly, search for other congenital anomalies.
- If there is any autoimmune disease, search for other autoimmune diseases.
- In all, search for medical problems.

C- Physical Examination:

- 1- Vital signs.
- 2- Airway.
- 3- Heart and lung.
- 4- Nervous system.
- 5- Other systems appearing affected by history.

D- Investigations and Laboratory Evaluation:

- It is generally accepted that the clinical history and physical examination represent the best methods of screening for the presence of diseases.

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- Routine laboratory tests in patients who are apparently healthy by clinical history and examination are invariably of little use and a waste of resources.
 - Before ordering extensive investigations, the anesthesiologist should ask himself the following questions.
 - 1- Will these investigations yield more information not revealed by physical examination?
 - 2- Will the results of the investigations change the management of the patient?
 - Any disease detected by history or physical examination must be evaluated by more detailed investigations.
 - Recommended routine preoperative laboratory evaluation of an apparently healthy patient are:-
 - 1- **Hematocrit or Hb concentration:**
 - In • All patients > 60 years of age.
 - All menstruating females.
 - If significant blood loss is expected and/or blood transfusion.
 - All Asian patients (for sickle cell anemia).
 - 2- **S. glucose or s. creatinine (or BUN):**
 - In • All patients > 60 years of age.
 - Patients with history of diabetes, renal, hepatic diseases or receiving medications as steroids or nephrotoxic drugs.
 - 3- **Chest x-rays:**
 - In • All patients > 60 years of age.
 - Patients with history of cardiac, respiratory diseases or cancer (for secondaries).
 - 4- **ECG:**
 - In • All patients > 40 years of age.
 - Patients with history of cardiac diseases.
 - 5- **Liver function tests:**
 - In • Patients with hepatic or nutritional diseases.
 - Patients with history of chronic alcoholism (> 80 gm/ day).
- N.B.; Routine testing for AIDS or hepatitis is highly controversial.

E- Risk Assessment

- It is detection of pre-, intra-, and postoperative risk factors which increase mortality and morbidity.
- Over a broad range of surgery and patient age, the overall mortality rate from surgery is 0.6 %. This is many times greater than the overall mortality rate attributable to anesthesia per se ($\approx 0.001\%$).

a- ASA physical status classification:

- By American Society of Anesthesiologists in 1961.
- It should be applied to all patients who present for surgery although it does not embrace all aspects of anesthetic risks e.g. age and difficult intubation.

Class	Definition	Perioperative Mortality Rates
1	A normal healthy person	$\approx 0.1\%$
2	A patient with mild systemic disease and no functional limitations.	$\approx 0.3\%$
3	A patient with moderate to severe systemic disease that results in some functional limitations.	$\approx 3\%$

4	A patient with severe systemic disease that is a constant threat to life and functionally incapacitating.	≈ 15 %
5	A moribund patient who is not expected to survive 24 hours with or without surgery.	≈ 30 %
6	A brain-dead patient whose organs are being harvested.	
E	If the procedure is an emergency , the physical status is followed by suffix E e.g. 2E).	

It was originally 5 classes. A 6th category was later added to address the brain-dead organ donor.

b- Other system assessment:

- 1- CVS assessment E.g. Goldman's index of cardiac risk in non-cardiac procedure (see CVS)
- 2- Respiratory assessment.
- 3- CNS assessment.
- 4- Renal and liver disease assessment.

Q: Discuss risk assessment?

F- Informed Consent

- When the patient is a minor or otherwise not competent to consent, the consent must be obtained from someone legally authorized to give it, such as a parent, guardian or close relative.
- Informed consent i.e. **to ensure that the patient (or guardian) has sufficient information about the procedure and its risks** to make a reasonable and prudent decision whether to consent or not.

G- Preoperative Patient Preparation:

- In principle, if there is any medical condition which may be improved (e.g. pulmonary diseases, hypertension, cardiac failure, renal disease, shock, and diabetes) surgery should be postponed and appropriate managements should be instituted.
- Assessing complicated medical problems may require consultations with other specialists.

H- Premedications:

Definitions:

It is administration of drugs in the period 1 -2 hours before induction of anesthesia.

It includes;

1- **Benzodiazepines:** They are used for

a- **Anxiolysis** (decrease anxiety and fear without decreasing level of consciousness, it is only measured by the patient). It is the main goal and essential for nearly all patients.

N.B.; **Psychotherapy** via doctor-patient relationship **is the most important anxiolytic**.

b- **Sedation** (decrease activity and excitement with decreasing level of consciousness, the patient may appear to an observer adequately sedated but on questioning may be quite anxious).

c- **Amnesia** (loss of memory).

Especially in pediatrics.

2- **Anticholinergics:** They are used

a- **Antisialagogue** (decrease salivary secretions).

Especially with ketamine or ether anesthesia.

b- **To decrease vagal reflexes**

Especially in ● Eye muscle traction especially medial rectus.

● Repeated suxamethonium.

● Induction with halothane in pediatrics.

● Opioids/ relaxant technique with surgical stimulation.

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3- **Antiemetics:** e.g. metoclopramide, ondansetron,.....

a- **To prevent aspiration** (decrease gastric volume and increase gastric pH).

Especially in obstetrics and emergency patients.

By metoclopramide.

b- **To decrease postoperative nausea and vomiting.**

Especially after opioids and biliary tract surgery.

4- **Antihistaminics:**

a- **H₁ blockers:**

To prevent allergic reactions

b- **H₂ blockers:** e.g. cimetidine or ranitidine

To prevent aspiration (decrease gastric volume and increase gastric pH).

Especially in obstetrics and emergency patients.

5- **Opioids:**

a- **To decrease sympathoadrenal responses** (as pressor response of intubation).

Especially in ischemic heart patient or hypertension.

b- **Analgesia**

For existing preoperative pain.

6- **Others:**

As antibiotics, anticoagulants,.....

- Anxiolysis is considered the only essential premedication.

Intraoperative Management

Intraoperative anesthetic record

Value

1- A useful intraoperative monitor.

2- A reference of the patient for future anesthesiologists.

3- Important for medico-legal purposes.

4- A tool for quality assurance.

Before induction of anesthesia,

1- Preoperative check of the anesthesia machine and other equipment.

2- Preanesthetic check of the correct patient for the correct operation.

3- Reevaluation of the patient immediately prior to induction including history, examination, investigation, consultations, and consent.

4- Application of the premedication.

Intraoperative management includes

I- Patient Monitoring:

- The standard recommended monitoring is 3 or 5 lead ECG, NIBP, pulse oximetry, endtidal CO₂.

- Other special monitorings are indicated according to the case.

II- Patient Position:

- All general anesthesia is induced in supine horizontal position then the patient position is readjusted according to the type of surgery.

- It includes:- Supine: horizontal, trendelenburg and reverse trendelenburg.

 - Prone

 - Lithotomy.

 - Lateral.

 - Sitting.

Positions are discussed later.

III- Choice of Anesthesia:

General, regional, local, or combined anesthesia.

IV- Induction of General Anesthesia:

a- Intravenous Induction:

- Indication: for most routine purposes.

- Technique:

- Check **i.v. cannula** first. Large i.v. cannula is used if expected blood loss, best in forearm or back of the hand. Avoid in antecubital fossa due to risk of intra-arterial cannulation. In children, EMLA cream (a local anesthetic) can be used.
- After monitors are applied, **preoxygenation** by a close-fitting face mask with 100 % O₂ is applied by Magill breathing system for 5 minutes (alternatively, 3-4 large breaths {vital capacity} may be used).
- Choose suitable i.v. anesthetic induction agent and calculate the suitable dose. A small test dose is administered commonly with observing its effect for early detection of hypersensitivity reactions or intra-arterial injection. Slow injection is required especially in patients with slow circulation time e.g. elderly, hypovolemia, shock or C.V.S. diseases with monitoring the effect of drugs on C.V.S. and respiratory system.
- **Rapid sequence induction** is indicated in patients who are at risk of vomiting and regurgitation e.g. obstetrics or emergency patients.
- I.v. induction agents induce rapid transition to stage 3 anesthesia.

b- Inhalational Induction:

- Indications:
- 1- Young uncooperative children without venous line.
 - 2- Upper airway obstruction e.g. epiglottitis.
 - 3- Lower airway obstruction e.g. with foreign body.
 - 4- Broncho-pleural fistula or empyema.
 - 5- No accessible veins.

- Technique:

- By using either;

- Anesthetic black mask (better with a clear face mask).

Or - Insufflation of the volatile agent over the face by placing the T-piece in the anesthetist's hand (no mask technique).

- The child can be allowed to sit during the early stages of induction.
- Start with a mixture of 70 % O₂ and 30 % N₂O then gradually increase N₂O till O₂:N₂O becomes 3 : 7 then add the volatile agent in 0.5 % increments every 3-5 breaths.
- In more co-operable patients, a single breath technique is used, as the patient is allowed to take one vital capacity breath from a prefilled 4 liter reservoir bag (in adults) or 2 liter bag (in children) containing high concentration of the volatile agent e.g. halothane 5 % or sevoflurane 8 %.
- Halothane or **sevoflurane** are usually used. Avoid isoflurane, or desflurane due to their pungent odor causing coughing, breath-holding and laryngospasm.
- After consciousness is lost, i.v. cannula is inserted and intubation is completed either by - muscle relaxant.
or - deepening anesthesia by increasing the concentration of volatile agents.
- N₂O is discontinued before intubation to allow the patient's lung to be filled with high inspired O₂ and produce high O₂ saturation to be maintained during period of apnea.
- Avoid +ve pressure ventilation before intubation as it may cause gastric distention which impairs lung expansion. If this occurs, a non-traumatizing naso-gastric tube is used to decompress the stomach.

THE PRACTICE CONDUCT OF ANESTHESIA**- Disadvantages:**

1- Slow induction of anesthesia.

2- Airway obstruction, bronchospasm, laryngospasm, hiccups or severe bradycardia. This may occur before i.v. access is available.

so,- Atropine i.m. 0.02 mg/kg (do not exceed 0.4 mg) for bradycardia.

- Suxamethonium i.m. 4-6 mg/kg (do not exceed 150 mg) for intubation.

Both should be available.

3- Environmental pollution.

c- Intramuscular Induction:

- Indication: for uncooperable combative child.

- By ketamine i.m. 5-10 mg/kg + suxamethonium i.m. 4-6 mg/kg (onset 3-4 min).

d- Rectal Induction (Steal Induction):

- Indication: for uncooperative children less than 20 kg body weight.

- Technique:

- Use either thiopental 30-44 mg/kg or methohexital 25-30 mg/kg 5-10 % solution (given in presence of parents) to induce sleep within 5-10 min , then the child is taken to the OR for steal induction. It may cause airway obstruction.

V- Airway Management:

See later

VI- Maintenance of Anesthesia:**a- Inhalational Anesthesia with Spontaneous Ventilation:**

- Indication:







1- Procedures which do not need muscle relaxation (superficial procedures).

2- Minor procedures as short operations or when little reflexes or pain is expected.

N.B.; it is not suitable for patients at risk of aspiration.

- **Guedel's classic signs of anesthesia (stages of anesthesia).**

They are seen in patients premedicated with atropine and morphine and anesthetized by ether but are not so obvious with recent inhalational agents.

Stage	Respiration	Pupils size	Eye reflexes	Respiration reflexes
1-Analgesia by 50% N ₂ O in O ₂	-Regular -Small volume		-All are present	-All are present
2-Excitement	-Irregular and erratic with breath holding		-Eyelash reflex is absent	
3-Anesthesia Plane I	-Regular -Large volume		-Eyelid reflexes are absent with resistance to lid elevation -conjunctival reflexes are depressed	-Pharyngeal reflexes ,vomiting and gag are depressed -Swallowing is present
Plane II	-Regular -Large volume		-Corneal reflexes are depressed	-Laryngeal reflexes are present e.g. anal stretch causing laryngeal spasm
Plane III (Surgical Plane)	-Regular -Be diaphragmatic -Small volume		-Lacrimation is absent	-Laryngeal reflexes are depressed
Plane IV	-Irregular -Be diaphragmatic -Small volume			-Carinal reflex is depressed

FLASHLIGHTS ON ANESTHESIA

4- Overdose	-Respiratory (and CVS) depression → apnea		-All brain stem reflexes are depressed then absent	-All brain stem reflexes are depressed then absent
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- Technique:

- By Magill breathing system with 70 % N₂O in O₂.
- The depth of anesthesia is controlled by volatile agents e.g. halothane 1-2 %, isoflurane 1-2 %. The depth of anesthesia is assessed by signs of inadequate depth of anesthesia (tachypnea, tachycardia, hypertension, sweating, lacrimation and reflex movement in response to surgery).

b- Relaxant Anesthesia:

- Indication:

- 1- Operations that need muscle relaxation e.g. major abdominal operations.
- 2- Major operations as
 - Lengthy operations (because spontaneous ventilation for a long time causes respiratory insufficiency)
 - Much pain is expected.
- 3- Abnormal positions interfering with spontaneous ventilation.

- Technique:

- A Non-depolarizing muscle relaxant is used after intubation with controlled ventilation and inhalational agents in doses less than MAC (\pm Opioids). Total i.v. anesthesia can be applied. It requires reversal of the residual muscle relaxation.

- Assessment: for

- 1- Adequacy of depth of anesthesia. as before

- 2- Awareness during anesthesia.

Especially with light anesthesia

e.g. • if N₂O is not used.

- if opioid is used with little or no inhalational agents.

- 3- Adequacy of muscle relaxation.

Signs of return of muscle tone during surgery are;

- Clinically;- Retraction of the wound edges during abdominal surgery.
 - Movement of abdominal muscle, diaphragmatic (hiccups) or facial muscles.
- By peripheral nerve stimulator.

- 4- Adequacy of ventilation.

Signs of inadequate ventilation are;

↑ PaCO₂ → venous dilatation, wound oozing, tachycardia, hypertension, attempts of patient spontaneous ventilation.

So, measurement of airway pressure and end expired PCO₂ are now strongly recommended with relaxant anesthesia and controlled ventilation.

VII- Intraoperative fluid therapy.

See later

VIII- Intraoperative complications and management.

See later

IX- Emergence and recovery.

- After tracheal extubation and discontinuing the anesthetic agent;

- 1- 100 % O₂ is given by a face mask.

- 2- Support patient's airway until respiratory reflexes are intact.

- 3- Assess the patient's muscle power and co-ordination e.g. testing hand grip, tongue protrusion, lifting unsupported head from the pillow in response to command.

Post-operative Management

The responsibility of anesthesiologists does not end by complete patient recovery from the effects of the anesthetics, but it continues till normal vital signs have been established and the patient's condition is seemed stable.

The patient is discharged from the operating room to post-anesthetic care unit (PACU) (recovery room) in which the anesthesiologist should remain with the patient till discharged from PACU.

Before discharge from PACU, a discharge note should be written by the anesthesiologist to document;

- The patient's recovery from anesthesia.
- Any apparent anesthesia-related complications and pain status and their management.
- The patient's immediate postoperative condition.
- The disposition i.e. discharge to

- An outpatient area.	- Inpatient ward.
- ICU	- Home.
- Inpatients should be seen again at least once by the anesthesiologist within 48 hours after discharge from PACU.

Approach of Anesthetic Management

- **Definition and pathophysiology** (+ causes and C/P)

- **Anesthetic problems**

I) Preoperative Management:

1- **Patient assessment:** (by history, examination, and investigations)

From C/P, other systems, drug therapy (side effects and interactions)

2- **Patient preparation:** (elective and emergency surgery)

3- **Premedications:** (sedatives, anticholinergics \pm aspiration prophylaxis)

II) Intraoperative management:

- **Monitoring**

- **Patient position**

- **Choice of anesthesia**

a- **Regional anesthesia** (advantages and disadvantages)

b- **General anesthesia** (advantages and disadvantages)

1- **Induction:** - Type of induction (smooth, crush,....etc)

- Induction agent

- Muscle relaxant

- ETT and pressor response.

2- **Maintenance:**

O₂ \pm N₂O + inhalational agents + opioids + muscle relaxant + mechanical ventilation

3- **Intraoperative problems** (causes and treatment)

4- **Fluid therapy**

5- **Body temperature control**

6- **Recovery and extubation** (awake or deep extubation)

(+ criteria of extubation and reverse of muscle relaxation)

III) Postoperative Management:

1- To ward or ICU.

2- Pain management.

3- Postoperative complications.

CHAPTER 3

PHARMACOLOGY Of ANESTHESIA

It includes:

- Theories of general anesthesia action.
- Inhalational anesthetic agents.
- Intravenous anesthetic agents.
- Skeletal muscle relaxants.
- Local anesthetic agents.
- Opioids
- Others

Definition of General Anesthesia

- It is an altered physiologic state in which, as a result of reversible, drug-induced unconsciousness, noxious stimuli can neither be perceived nor recalled.
 - General anesthetic agent: It is that drug which its primary effect is able to reversibly induce such a state.
 - Old definition: General anesthesia includes hypnosis (loss of consciousness), amnesia, analgesia & some degree of muscle relaxation.
- N.B.; The term "Anesthesia" was first suggested by **Oliver W. Holmes** in 1846.

Theories of General Anesthesia Action

There are many theories, but none of them completely explain the mode of action of all anesthetics.

Lipid Solubility Theory (The Unitary Hypothesis):

- It was originally developed in 1901 by HH Meyer & E Overton.
- It suggested that all anesthetics act by this theory (hence, the name unitary), as there is a correlation between anesthetic potency (MAC) & lipid solubility (Oil/gas partition coefficient). This is called Meyer Overton rule as the anesthetic molecules bind at specific lipophilic sites.
- But, of course not all lipid-soluble molecules are anesthetics.

Affection of Synaptic Transmission:

- It is the most recent. It was found that general anesthetics decrease synaptic transmission rather than axonal impulse conduction. This occurs by;

a) Presynaptic Mechanisms:

- ① Chronic depolarization i.e. activation of presynaptic K⁺ channels which decrease the amount of transmitter release per impulse by a mechanism similar to presynaptic inhibition.
- ② A decrease in presynaptic release of excitatory transmitters (as glutamate).
- ③ An increase in the uptake of excitatory transmitters (as glutamate).
- ④ A decrease in Ach re-synthesis. This is followed by presynaptic depletion of Ach which causes decreased synaptic transmission

b) Postsynaptic Mechanisms:

General anesthetics produce depression of postsynaptic response by:

PHARMACOLOGY OF ANESTHESIA

① Inhibition of nicotinic acetyl choline receptors → ↓ Ach transmission.

② Inhibition of glutamate receptors → ↓ glutamate transmission.

- Ketamine (& to a lesser extent isoflurane & enflurane) block N-methyl D-aspartate (NMDA) receptors, subtypes of glutamate receptors, which decreases glutamate (excitatory) transmission.

③ Stimulation of GABA_A receptors: → ↑ GABA (inhibitory) transmission.

All anesthetics increase synaptic transmission mediated by GABA (by increase Cl⁻ current).

This potentiates CNS inhibition. This potentiation occurs by;

① Increasing the open time of the Cl⁻ channel.

② Increasing the frequency of Cl⁻ channel opening.

③ Increasing affinity of GABA receptors to its natural agonist (GABA).

So, the channel opens at lower concentration of GABA.

Summary:

- General anesthetics act mainly at synaptic transmission rather than axonal impulse conduction.

- Anesthetics are selective in their action at a cellular and molecular level so, unitary hypothesis is unlikely nowadays.

- Based on the current evidence, proteins (and not lipids) are considered the primary target of general anesthetics.

INHALATIONAL ANESTHETIC AGENTS

Pharmacokinetic of Inhalational Anesthetics

A. Factors Affecting Inspiratory Concentration (Fi)

① Increasing fresh gas flow rate.

② Decreasing volume of the breathing system.

③ Decreasing absorption by anesthetic machine of the breathing system.

All → Closer inspired gas concentration to the fresh gas concentration.

B. Factors Affecting Alveolar Concentration (FA)

① Uptake:

- If there was no uptake of anesthetic agents by the body, the alveolar gas concentration (FA) would rapidly approach the inspired gas concentration (Fi), but actually there is an uptake of anesthetic agents by the body so, the alveolar gas concentration will be less than the inspired gas concentration i.e. $FA/Fi = < 1.0$

The greater the uptake of an anesthetic agent →

- The lower the rate of rise of the alveolar concentration.
- The greater the difference between inspired & alveolar concentrations.
- The slower the rate of induction & (also recovery).

- Factors affecting anesthetic uptake

① Solubility in blood (blood/gas solubility coefficient)

- Insoluble agents such as N_2O are taken up by the blood less avidly than are soluble agents such as halothane so, the alveolar concentration (& alveolar partial pressure) of N_2O rises faster than that of halothane. So, the onset of induction is faster with N_2O . The same applies to recovery from anaesthesia.
i.e.; the higher the blood/gas solubility coefficient, the greater the anesthetic solubility and the slower the onset of induction and recovery.

①

Onset of induction and recovery $\propto \frac{1}{\text{Blood/gas solubility coefficient}}$

② Alveolar blood flow

- Increased alveolar blood flow (in absence of pulmonary shunting) i.e. increased CO causes increase anesthetic uptake. This produces a slow rise of alveolar partial pressure (P_A) which in turn makes the onset of induction slow.

③ Partial pressure difference between alveolar gas & venous blood ($P_A - P_V$)

If the anesthetic did not pass into organs (as brain), venous & alveolar partial pressures would become identical and there would be no pulmonary uptake, but actually there is a transfer of anesthetics from blood to tissues which is determined by 3 factors; • Tissue solubility of the agent.

- Tissue blood flow.
- Partial pressure difference between arterial blood & the tissue.

Tissues are classified into

Type of Tissues	CO%	Relative solubility
① Vessel-rich group: Brain, heart, liver, kidney & endocrine glands.	75	1
② Muscle group: Skin & muscles.	19	1
③ Fat group:	6	20
④ Vessel-poor group: Bone, ligaments, teeth, hair & cartilages	0	0

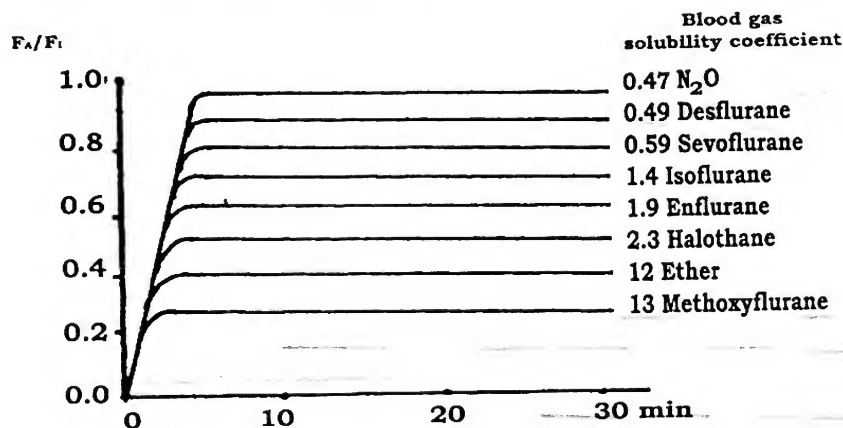


Figure 3-1; F_A rises toward F_i faster with N_2O than with methoxyflurane

PHARMACOLOGY OF ANESTHESIA**② The rate of delivery of the anesthetic agent to the alveoli:**

depends on

- ① **Ventilation:** increasing the ventilation causes increased delivery of anesthetic agents to the alveoli which compensates for their uptake. This maintains alveolar concentration causing more rapid onset of induction.
- ② **Concentration:** increasing the concentration (by adjusting the vaporizer) leads to an increase of alveolar concentration and its rate of rise i.e. concentrating effect, but this is limited due to the irritant effect on the airway in a spontaneously breathing patient.
- ③ **Apparatus dead space:** its decrease causes an increase in the rate of delivery of anesthetic agents.

C. Factors affecting arterial concentration (F_a)

Mainly ventilation/ perfusion (V/Q) mismatching.

- Normally, alveolar and arterial anesthetic partial pressures are assumed to be equal.
- The presence of V/Q mismatching increases alveolar-arterial differences i.e. increased alveolar partial pressure (especially for highly soluble agents) and decreased arterial partial pressure (especially for poorly soluble agents).

Pharmacodynamics of Inhalational Anesthetics**Theories of Anesthetic Action:**

See before

Minimum Alveolar Concentration (MAC)

Definition: It is the minimum alveolar concentration of an anesthetic at 1 atmosphere absolute that prevents movement of 50% of the population to a standard stimulus (e.g. surgical incision).

N.B.:- MAC values for different anesthetics are roughly additive (see MAC values later)

E.g. a mixture of 0.5 MAC of N_2O (53%) & 0.5 MAC of halothane (0.37%) approximates the degree of CNS depression of 1.0 MAC of enflurane (1.7%).

- MAC represents only one point on the dose-response curve. It is the equivalent of an effective dose 50 (ED₅₀).

Types of MAC:

- ① **MAC:** as above
- ② **MAC awake:** It is the minimal alveolar concentration allowing voluntary response to command in 50 % of patients (e.g. open your eyes). It is 0.3 – 0.4 times MAC i.e. 30-40% of MAC for isoflurane, desflurane & sevoflurane and it is 0.7 times MAC for N_2O .
- ③ **MAC_{95%}:** It is the MAC that prevents movement in about 95% of patients (an approximation of the ED_{95%}). It is 1.3 times MAC of any of the volatile anesthetics.
- ④ **MAC intubation:** It is the MAC that allows intubation without muscle relaxant coughing or bucking in 50% of patients.

Factors affecting MAC:

Factors ↓ MAC (CNS depression)	Factors ↑ MAC (CNS excitation)
① Hypothermia & hyperthermia	① Hyperthermia > 42°C
② Age: elderly	② Young
③ Alcohol: acute toxicity	③ Chronic abuse

<p>④ <u>Myxoedema</u></p> <p>⑤ <u>Hyponatremia</u></p> <p>⑥ <u>Drugs:</u></p> <ul style="list-style-type: none"> • α_2 agonists e.g. <u>methyl dopa</u>, <u>reserpine</u>, <u>clonidine</u> (they <u>decrease</u> the <u>sympathetic activity</u>). • <u>Chronic amphetamine</u> • <u>Local anesthetics</u> (except <u>cocaine</u>) • <u>Others</u>; <u>N₂O</u>, <u>barbiturates</u>, <u>ketamine</u>, <u>opioids</u>, <u>benzodiazepines</u> 	<p>④ <u>Thyrotoxicosis</u></p> <p>⑤ <u>Hypernatremia</u></p> <p>⑥ <u>Drugs:</u></p> <ul style="list-style-type: none"> • <u>Sympathomimetics</u> e.g. <u>cocaine</u>, <u>ephedrine</u> (they <u>increase</u> the <u>sympathetic activity</u>). • <u>Acute amphetamine</u>. • <u>Cocaine</u>.
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Q: What is called MAC in anesthesia?

A: MAC = Minimal Alveolar Concentration.

MAC = Monitor Anesthesia Care e.g. during regional anesthesia of the eye, critically ill patients doing procedures without anesthesia.

Inhalational anesthetic

includes;

- ① Nitrous Oxide (N₂O; laughing gas): inorganic anesthetic.
- ② Halothane: halogenated hydrocarbon (halogenated alkene) i.e. R—R
- ③ Ether: one of ethers; diethyl ether.
- ④ Methoxyflurane: one of ethers; halogenated methyl ethyl ether.
- ⑤ Enflurane: one of ethers.
- ⑥ Isoflurane: one of ethers; isomer of enflurane.
- ⑦ Desflurane: one of ethers.
- ⑧ Sevoflurane: one of ethers; methyl propyl ether.

Ethers are R—O—R

N.B.; - M.W. = Molecular Weight

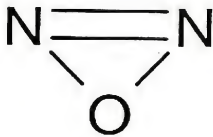
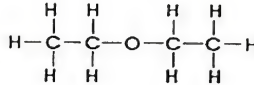
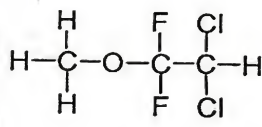
- SVP = saturated vapor pressure at 20 °C
- BP = Boiling Point
- V_t = Tidal Volume.

- Da = Dalton

- KPa = Kilopascal

- RR = Respiratory rate.

PHARMACOLOGY OF ANESTHESIA

	Nitrous Oxide	Ether (Diethyl Ether)	Methoxyflurane (Penthrane)
Chemical Structure			
Physical Values	- M.W (Da) <u>44</u> - SVP (KPa) at 20 °C <u>5300</u> - Boiling point (°C) <u>-88</u> - Critical temperature (°C) <u>36.5</u> - Critical pressure (bar) <u>72.6</u>	- M.W. <u>74</u> - SVP <u>56.5</u> - BP <u>35</u>	- MW <u>165</u> - SVP <u>3</u> - BP <u>105</u>
Physical Properties	- <u>Non-flammable and non-explosive</u> but <u>supports combustion</u> . - <u>Colorless and odorless</u> (slight <u>sweet odor</u>). - <u>Stable</u> . - Stored as a <u>liquid</u> in a <u>blue cylinder</u> at pressure <u>47-50 bar</u> . Its <u>total quantity</u> is assessed by <u>weighing</u> .	- <u>Highly flammable and highly explosive</u> . - <u>Colorless and characteristic odor</u> . - <u>Decomposed by air, light and heat</u> but <u>stable with soda lime</u> . - Stored in <u>opaque bottles</u> .	- <u>Non-flammable and non-explosive</u> . - <u>Colorless and sweet fruity odor</u> . - <u>Decomposed by light</u> ; stabilized with <u>butylated hydroxytoluene</u> . - Stored in <u>opaque bottles</u> .
MAC and Onset	- MAC = <u>105 %</u> (hyperbaric condition is <u>needed</u>). - <u>Fastest induction and fastest recovery</u> as has the <u>lowest blood/gas coefficient</u> = <u>0.47</u>	- MAC = <u>1.9 %</u> - <u>Slow induction and slow recovery</u> as has <u>high blood/gas coefficient</u> = <u>12</u> and <u>irritant to respiratory tract</u> .	- MAC = <u>0.2% (the most potent)</u> - <u>Slow induction and slow recovery</u> as has <u>high blood/gas coefficient</u> = <u>13</u>
Excretion & Metabolism (Rule of 2)	- The <u>main route of excretion</u> of all anesthetic agents are the <u>lungs</u> . - <u>Metabolism</u> occurs in the <u>liver</u> by cytochrome P-450 isoenzymes (specifically CYP2E1).		
Toxicity	• <u>No or very small</u> (0.004%) percent are metabolized in the <u>liver</u> . It is almost all <u>eliminated unchanged by exhalation</u> .		
Q: What are the precautions of prolonged anesthesia?	- Toxicity: On <u>prolonged exposure > 6-8 hours</u> ① It <u>irreversibly oxidizes</u> the <u>cobalt atom</u> in <u>vitamin B₁₂</u> → <u>inhibition of vitamin B₁₂ dependent enzymes</u> as: • <u>Methionine synthetase</u> → <u>impairs myelination synthesis</u> → <u>CNS deficiency as peripheral neuritis and myelo-neuropathy</u> • <u>Thymidylate synthetase</u> → <u>impairs DNA synthesis</u> → <u>megaloblastic anemia, agranulocytosis, bone marrow aplasia</u> . ② <u>Possible teratogenic effect</u> so should be <u>avoided in early pregnancy</u> . ③ It changes the <u>immune response</u> to <u>infection</u> by affecting <u>chemotaxis</u> and <u>WBCs motility</u> .		
	• <u>20%</u> are metabolized in the <u>liver</u> <u>15%</u> are metabolized to <u>CO₂ and H₂O</u> <u>4%</u> are metabolized to <u>acetaldehyde & ethanol</u> .		
	• <u>45-50%</u> (extensive) are <u>metabolized</u> (especially in <u>obese and elderly</u>) → <u>oxidative metabolites as free fluoride and oxalic acid</u> . - Toxicity: ① <u>Hepatic toxicity is rare</u> ② <u>Nephrotoxicity</u> : As <u>fluoride</u> → • <u>Vasopressin-resistant high-output renal failure</u> <u>"nephrogenic diabetes insipidus"</u> (diagnostic of <u>methoxyflurane toxicity</u>). • <u>Direct inhibition of tubular function</u> → <u>concentration defect</u> .		

Halothane (Fluothane)	Enflurane	Isoflurane	Desflurane	Sevoflurane
$\begin{array}{c} \text{F} \quad \text{Cl} \\ \quad \\ \text{F}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{F} \quad \text{Br} \end{array}$ <p>2-bromo-2-chloro-1,1,1-trifluoro-ethane "CF₃CHClBr"</p>	$\begin{array}{c} \text{F} \quad \text{F} \quad \text{Cl} \\ \quad \quad \\ \text{H}-\text{C}-\text{O}-\text{C}-\text{C}-\text{H} \\ \quad \quad \\ \text{F} \quad \text{F} \quad \text{F} \end{array}$	$\begin{array}{c} \text{F} \quad \text{H} \quad \text{F} \\ \quad \quad \\ \text{H}-\text{C}-\text{O}-\text{C}-\text{C}-\text{F} \\ \quad \quad \\ \text{F} \quad \text{Cl} \quad \text{F} \end{array}$	$\begin{array}{c} \text{F} \quad \text{H} \quad \text{F} \\ \quad \quad \\ \text{H}-\text{C}-\text{O}-\text{C}-\text{C}-\text{F} \\ \quad \quad \\ \text{F} \quad \text{F} \quad \text{F} \end{array}$	$\begin{array}{c} \text{F} \\ \\ \text{F}-\text{C}-\text{F} \\ \quad \\ \text{F} \quad \text{F}-\text{C}-\text{H} \\ \quad \quad \\ \text{H} \quad \text{F}-\text{C}-\text{F} \\ \\ \text{F} \end{array}$
<p>CF₃CHClBr</p>		<p>CF₃CHCl O CF₂H</p>		<p>CH(CF₃)₂OCH₂F</p>
<p>- M.W. <u>197</u></p> <p>- SVP <u>32</u></p> <p>- Boiling point <u>50</u></p> <p>N.B.; Halothane and isoflurane can be used in the same vaporizer due to the same SVP</p>	<p>- M.W. <u>184.5</u></p> <p>- SVP <u>23</u></p> <p>- BP <u>56</u></p>	<p>- MW <u>184.5</u></p> <p>- SVP <u>32</u></p> <p>- BP <u>49</u></p>	<p><u>168</u></p> <p><u>89</u></p> <p><u>23.5</u></p>	<p><u>200</u></p> <p><u>21</u></p> <p><u>58.5</u></p>
<p>- Non-flammable and non-explosive.</p> <p>- Colorless and relative pleasant odor.</p> <p>- Decomposed by light, heat and soda lime (but used safely with soda lime).</p> <p>- Stored in opaque bottles with 0.01% thymol as a preservative → acute lung injury. Therefore, it is recommended to evacuate the vaporizer every 2-3 weeks completely.</p>	<p>- Nonflammable and non-explosive.</p> <p>- Colorless and sweet ethereal odor</p> <p>- Stable with soda lime.</p> <p>- Stored in opaque bottles with no preservative.</p>	<p>- Nonflammable and non-explosive</p> <p>- Colorless and pungent odor.</p> <p>- Stable with soda lime.</p> <p>- Stored in opaque bottles with no preservative.</p>	<p>- Nonflammable and non-explosive</p> <p>- Colorless and much less pungent odor</p> <p>- Stable with soda lime.</p> <p>- Stored in opaque bottles with no preservative</p>	<p>- Nonflammable and non-explosive</p> <p>- Colorless and pleasant odor</p> <p>- Hydrolysis in soda lime and H₂O with low fresh gas rates (see toxicity)</p> <p>- Stored in opaque bottles with no preservative</p>
<p>- MAC <u>0.75%</u></p> <p>- Relatively rapid induction (less than enflurane & isoflurane) as relatively low blood/gas coefficient <u>2.3</u></p>	<p>- MAC <u>1.68%</u></p> <p>- Rapid induction and recovery as low blood/gas coefficient <u>1.9</u> and pleasant non-irritant odor.</p>	<p>- MAC <u>1.15%</u></p> <p>- Rapid induction (but limited) and more rapid recovery as low blood/gas coefficient <u>1.4</u> Its pungent odor → ↑ coughing and breath-holding So, clinically not more than halothane</p>	<p>- MAC <u>6-9 (7.3)</u></p> <p>- The most rapid induction (but limited) and the most rapid recovery as very low blood/gas coefficient <u>0.49</u>. Pungent odor is irritant so avoided in children.</p>	<p>- MAC <u>2.0%</u></p> <p>- Rapid induction as low blood/gas coefficient <u>0.59</u> and not irritant and slower recovery (than desflurane) as high partition coefficient in vessel rich tissues, "muscle & fat"</p>
<p>- The main route of excretion of all anesthetic agents are the lungs.</p>				
<p>- Metabolism occurs in the liver by cytochrome P-450 isoenzymes (specifically CYP2E1).</p>				
<p>• 20% are metabolized by oxidative pathway → bromine, chlorine, trifluoroacetic acid and trifluoro-acetyl ethanol amide → excreted in urine.</p> <p>• A small % by reductive pathways (i.e. in absence of O₂) to reactive metabolites and fluoride (in concentrations lower than those which induce renal dysfunction). It occurs in presence of hypoxia, or phenobarbitone which → hepatic microsomal enzyme induction.</p> <p>- Toxicity: Halothane Hepatitis</p>	<p>• 2.0% are metabolized by defluorination → fluoride especially in obese patient.</p> <p>- Toxicity:</p> <p>① Hepatotoxicity: very rare (< halothane) Cross sensitization is reported between it and halothane so, multiple exposure to both should be avoided within short periods.</p> <p>② Nephro-toxicity: Fluoride level does not reach the renal toxic level.</p>	<p>• 0.2% are metabolized by oxidation → trifluoroacetic acid and difluoro methanol which → formic acid and fluoride.</p> <p>- Toxicity:</p> <p>① Hepatotoxicity Extremely rare (isoflurane < enflurane < halothane)</p> <p>② Nephrotoxicity Fluoride level does not reach the renal toxic level.</p>	<p>• 0.02 % → trifluoro-acetic acid and very little fluoride.</p> <p>- Toxicity: Hepatotoxicity only one case has been reported.</p>	<p>• 2% → fluoride (> Isoflurane).</p> <p>- Toxicity Nephrotoxicity: It is better avoided in patients with renal impairment due to fluoride and compound A, "an olefin" (see later)</p>

PHARMACOLOGY OF ANESTHESIA

	Nitrous Oxide	Diethyl ether	Methoxyflurane
Action	- It is a <u>good analgesic</u> but a <u>weak anesthetic</u> .	- It <u>depresses the cerebral cortex</u> → <u>loss of higher inhibition initially</u> followed by <u>depression</u> . All the <u>classical stages of anaesthesia</u> are seen due to <u>slow induction</u> .	- It <u>depresses the cerebral cortex</u> → <u>potent anesthetic</u> . - Cerebral VD → <u>↑ cerebral blood flow</u> → <u>mild ↑ ICT</u> .
① CNS	- Cerebral VD → <u>↑ cerebral blood flow</u> → <u>mild ↑ ICT</u> . - The <u>only agent</u> that <u>↑ cerebral O₂ consumption (CMRO₂)</u> because it stimulates cerebral cortex, (other agents ↓ CMRO ₂)		
② Respiration	① <u>Not irritant</u> to respiratory tract. ② <u>↑ RR & ↓ Vt</u> → net effect is <u>minimal change in minute ventilation and PaCO₂</u> . ③ <u>Markedly depresses the hypoxic drive</u> even with <u>small concentrations</u> .	① <u>Irritant to respiratory tract</u> → <u>coughing, breath-holding</u> and <u>profuse secretions</u> from <u>salivary and bronchial mucus glands</u> so, <u>premedication with atropine or hyoscine</u> is essential. ② It may cause <u>laryngeal spasm</u> during <u>induction</u> but on <u>established anaesthesia</u> → <u>bronchodilatation</u> . ③ It <u>↑ minute ventilation</u> with <u>↑ depth of anaesthesia</u> till <u>surgical stage</u> is reached then <u>gradual ↓ minute ventilation</u> as <u>plane 4 of stage 3</u> is approached.	① <u>Not irritant</u> . ② <u>Mild bronchodilating effect</u> ③ <u>↑ RR & ↓ Vt</u> → net effect is <u>↓ minute ventilation</u> → <u>↑ resting PaCO₂</u> .
③ CVS All volatiles may <u>protect the heart</u> against periods of <u>hypoxia</u> i.e. <u>pre-conditioning</u> especially <u>isoflurane</u> and <u>desflurane</u> .	① It directly <u>depresses myocardial contractility</u> <u>in vitro but in vivo</u> → • In <u>normal persons</u> , this effect is <u>antagonized by indirectly mediated sympatho-adrenal stimulation</u> → <u>little change in ABP, CO, & HR</u> . • In <u>patients with preexisting high levels of sympatho-adrenal activity</u> and <u>poor myocardial contractility</u> or <u>receiving β blockers</u> → <u>marked ↓ ABP, CO & HR</u> . ② <u>VC of pulmonary vessels</u> → <u>↑ pulmonary vascular resistance</u> → <u>↑ right atrial pressure</u> . ③ <u>Arrhythmias</u> may occur due to <u>indirect sympatho-adrenal stimulation</u> → <u>↑ circulatory catecholamines</u> .	① It directly <u>depresses myocardial contractility</u> <u>in vitro, but in vivo</u> → • <u>Light anaesthesia; indirectly mediated sympatho-adrenal stimulation</u> . • In <u>patients with deep anaesthesia</u> or <u>preexisting high levels of sympatho-adrenal activity</u> and <u>poor myocardial contractility</u> or <u>receiving β blockers</u> → <u>marked ↓ ABP, CO & HR</u> . ② <u>Arrhythmias</u> are <u>rare</u> because there is <u>no sensitization of the myocardium to catecholamines</u> .	① It directly <u>depresses myocardial contractility</u> → <u>↓ ABP & CO</u> but, <u>HR usually ↑</u> .
④ Neuro-muscular Effect	- <u>No muscle relaxation</u> - It <u>slightly potentiates muscle relaxants</u> . - It is <u>not a triggering agent of malignant hyperthermia</u> .	- It <u>relaxes muscle & potentiates non-depolarizing muscle relaxant</u> .	- It <u>relaxes muscle & potentiates non-depolarizing muscle relaxant</u> . - It is a <u>triggering agent of malignant hyperthermia</u> .
⑤ Renal	- <u>↓ renal blood flow</u> → <u>↓ GFR</u> → <u>↓ UOP</u> due to <u>↑ renal vascular resistance</u> .	- <u>↓ renal blood flow</u> → <u>↓ GFR</u> → <u>↓ UOP</u> .	- <u>↓ renal blood flow</u> → <u>↓ GFR</u> → <u>↓ UOP</u> . - It may cause <u>postoperative high output RF (toxicity)</u>
⑥ Hepatic	- <u>↓ hepatic blood flow</u> , but to a <u>lesser extent than other agents</u> .	- <u>↓ hepatic blood flow</u> .	- <u>↓ hepatic blood flow</u> .

N.B.: N₂O, ether, and ketamine have two actions on CVS;

1- Direct action: depression of the myocardium.

2- Indirect action: stimulation of sympatho-adrenal system → stimulation of catecholamine (CAs) release.

Halothane	Enflurane	Isoflurane	Desflurane	Sevoflurane
<ul style="list-style-type: none"> - It depresses the cerebral cortex → <u>good anesthesia</u>, but <u>weak analgesia</u>. - Cerebral VD → <u>↑ cerebral blood flow</u> → <u>↑↑ ICT</u>. - There is <u>emergence agitation</u>. 	<ul style="list-style-type: none"> - As halothane..... except on EEG → dose-dependent depression, but at moderate to high concentration (>3%) → <u>epilepti-form paroxysmal spike activity</u> and <u>burst suppression</u> and <u>twitching of face and arm muscle</u> therefore, it is <u>avoided</u> in epileptic patients. 	<ul style="list-style-type: none"> - As halothane..... except cerebral VD occurs at high concentration only → <u>↑ cerebral blood flow</u> → <u>↑ ICT</u>. 	<ul style="list-style-type: none"> - As halothane..... 	<ul style="list-style-type: none"> - As halothane... except <u>slight ↑ ICT</u>, more <u>emergence agitation</u> (treated with 1-2 $\mu\text{g/kg}$ fentanyl)
<ol style="list-style-type: none"> ① Not irritant. ② Potent bronchodilator due to central effect and β action. ③ In unpremedicated (i.e. no opioid) patient → <u>↑ RR</u> & <u>↓↓ Vt</u> i.e. rapid shallow breathing → net effect is <u>↓ minute ventilation</u> → <u>↑ resting PaCO₂</u> due to central respiratory depression. ④ It markedly depresses <u>hypoxic drive</u>. ⑤ It depresses <u>mucociliary function</u> (may be for hours post-operatively → sputum retention). 	<p>As halothane..... except <u>more respiratory depression</u> (enflurane > desflurane > isoflurane > halothane > sevoflurane)</p>	<p>As halothane..... except <u>irritant</u> to respiratory tract → <u>coughing</u>, <u>breath-holding</u> and <u>profuse secretions</u> from <u>salivary</u> and <u>bronchial glands</u>.</p>	<p>As isoflurane.....</p>	<p>As halothane except it is suggested to have the <u>least effect on respiration</u> among all inhalational agents.</p>
<ol style="list-style-type: none"> ① <u>↓ Myocardial contractility</u> → <u>↓ CO</u> (dose dependent) ② <u>↓ Systemic vascular resistance</u> → <u>VD</u> → <u>↓ ABP</u>. ③ <u>Central vagal stimulation</u> (and abolishment of baroreceptor reflex due to <u>↓ ABP</u>) → <u>↓ HR</u> which is antagonized by <u>atropine</u>. ④ <u>↑ right atrial pressure</u>. ⑤ Arrhythmias: (halothane > enflurane > isoflurane due to - <u>↑ myocardial excitability</u> augmented by <u>hypercapnia</u>, <u>hypoxia</u>, <u>↑ circulating CAs</u> - <u>Central vagal stimulation</u> → <u>bradycardia</u>.) ⑥ <u>↓ Coronary blood flow</u>, but <u>↓ contractility</u> and <u>↓ HR</u> → <u>↓ O₂ demand</u> so, it is of advantage in patients with <u>coronary artery disease</u>. 	<p>As halothane..... except;</p> <ul style="list-style-type: none"> - <u>No central vagal stimulation</u> so, there is <u>reflex ↑ HR</u> with <u>↓ ABP</u>. - <u>Less arrhythmias</u>. 	<p>As enflurane except;</p> <ul style="list-style-type: none"> - In <u>coronary vessels</u>, there is possibility of <u>coronary steal phenomenon</u> as <u>VD</u> occurs in normal coronary artery → as it has <u>low resistance</u> to flow so, <u>↓ perfusion</u> via <u>stenosed vessels</u> so, it is <u>controversy</u>, in patients with <u>coronary disease</u>. - <u>↑ incidence of myocardial ischemia</u> due to <ol style="list-style-type: none"> 1. <u>Coronary steal</u>. 2. <u>↑ HR</u> & <u>↓ ABP</u>. 3. <u>↑ LVEDP</u> & <u>↓ LV compliance</u>. 	<p>As isoflurane... except;</p> <ul style="list-style-type: none"> - <u>Slight effect</u> on <u>ABP</u> & <u>HR</u> - <u>CO</u> is maintained as <u>↓ contractility</u> and <u>↓ SVR</u> causing <u>↓ ABP</u> are <u>antagonized</u> by <u>↑ HR</u> - <u>Less coronary VD</u> and <u>no steal phenomenon</u>. 	<p>As desflurane except;</p> <ul style="list-style-type: none"> - there is <u>no ↑ HR</u> therefore; <u>CO</u> can be <u>decreased</u> unlike <u>desflurane</u> and <u>isoflurane</u>.
<ul style="list-style-type: none"> - It <u>moderately relaxes skeletal muscles</u> & <u>potentiates non-depolarizing muscle relaxants</u> - It is a <u>triggering agent</u> for <u>malignant hyperthermia</u>. - <u>Postoperative shivering</u> → <u>↑ O₂ requirement</u> → <u>hypoxia</u> unless <u>O₂</u> is <u>given</u>. 	<ul style="list-style-type: none"> - It <u>strongly relaxes</u> and..... 	<ul style="list-style-type: none"> - It <u>strongly relaxes</u> And..... 	<ul style="list-style-type: none"> - It <u>strongly relaxes</u> and..... 	<ul style="list-style-type: none"> - It <u>moderately relaxes</u> and.....
<ul style="list-style-type: none"> - <u>↓ RBF</u> → <u>↓ GFR</u> → <u>↓ UOP</u> due to (<u>↓ ABP</u> & <u>↓ CO</u>). In some texts, it does <u>not ↓ RBF</u> because it <u>↓ renal vascular resistance</u> and <u>perfusion pressure</u> proportionately. - <u>↓ hepatic blood flow</u>. - <u>Hepatic dysfunction</u>. 	<ul style="list-style-type: none"> - <u>↓ RBF</u> → <u>↓ GFR</u> → <u>↓ UOP</u>. - <u>↓ hepatic blood flow</u>. 	<ul style="list-style-type: none"> - <u>↓ RBF</u> → <u>↓ GFR</u> → <u>↓ UOP</u> especially in <u>high doses</u>. - <u>↓ hepatic blood flow</u>. 	<ul style="list-style-type: none"> - <u>↓ RBF</u> → <u>↓ GFR</u> → <u>↓ UOP</u>. - <u>↓ hepatic blood flow</u>. 	<ul style="list-style-type: none"> - <u>↓ RBF</u> → <u>↓ GFR</u> → <u>↓ UOP</u>. - <u>↑ hepatic blood flow</u>.

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	Nitrous Oxide	Diethyl ether	Methoxyflurane
Others	<p>- GIT: It may cause <u>postoperative nausea & vomiting</u> due to <u>stimulation of chemoreceptor trigger zone "CTZ"</u> and <u>vomiting centre in medulla</u>.</p>	<p>- GIT: • <u>↑ secretions</u> during <u>light</u> and <u>↓</u> during <u>deep</u> anesthesia. • <u>GIT motility ↓</u> • <u>Postoperative nausea & vomiting ↑</u> due to <u>vomiting center stimulation</u> and it <u>dissolves in saliva</u> → <u>swallowed</u> → <u>stomach irritation</u> - <u>Uterus:</u> <u>Light anesthesia</u> → <u>no effect</u> <u>Deep anesthesia</u> → <u>relaxation</u>.</p>	
Contra-indication	<p>① <u>Effect on closed gas spaces</u>: as N_2O is <u>35 times more soluble</u> than <u>nitrogen</u> in <u>blood</u>, thus it tends to <u>diffuse</u> into <u>air-containing cavities</u> more <u>rapidly</u> than <u>nitrogen</u> is <u>absorbed</u> by the <u>blood stream</u> → <u>↑ volume of closed compliant space</u> and <u>↑ tension of closed non-compliant space</u>. So it is <u>contraindicated</u> in <u>air embolism</u>, <u>acute intestinal obstruction</u>, <u>pneumothorax</u>, <u>pulmonary air cyst</u>, <u>intraocular air bubbles</u>, <u>tympanic membrane grafting</u>. N_2O also <u>diffuses</u> into <u>ETT cuffs</u> → <u>↑ its pressure</u> against <u>tracheal wall</u>.</p> <p>② <u>Pulmonary hypertension</u>: it <u>↑ pulmonary vascular resistance</u></p>	<p>① <u>Diabetes mellitus</u> because it stimulates <u>gluconeogenesis</u> → <u>hyperglycemia</u>. ② <u>Severe liver disease</u>. ③ <u>Fever</u> especially in <u>children</u> as may cause <u>convulsions</u>.</p>	<p>- <u>Renal impairment</u></p>
Drug interaction	<p>① It can <u>not be used alone</u>, but <u>with other volatiles</u>. ② <u>Slight non-depolarizing muscle relaxant potentiation</u> ③ <u>Concentration effect</u>: N_2O is <u>more soluble</u> in <u>blood</u> than <u>nitrogen</u> so, the <u>volume of N_2O entering pulmonary capillary blood from the alveoli</u> is <u>greater</u> than the <u>volume of nitrogen moving in the opposite direction</u> → the <u>total volume of gas in the alveoli</u> <u>↑</u> → <u>↑ fractional concentration of the remaining gases</u> i.e. O_2, CO_2, and <u>halothane</u>. The <u>higher the inspired concentration of N_2O</u>, the <u>greater is the concentrating effect</u>. <u>2nd gas effect</u>: When N_2O is inspired in <u>high concentration</u> with a <u>2nd anesthetic gas</u> e.g. <u>halothane</u> → N_2O <u>absorption</u> → <u>↑ alveolar concentration of halothane</u> (concentrating effect) → <u>↑ rate of equilibrium</u> with inspired gas. ④ <u>Diffusion hypoxia</u>: At the <u>end of anesthesia</u>, when <u>inspired gas mixture</u> is changed from N_2O/O_2 to N_2/O_2 so, the <u>volume of N_2O diffusing from mixed venous blood into the alveolus</u> is <u>greater</u> than <u>volume of nitrogen taken up from the alveolus into pulmonary capillary blood</u> (the <u>opposite of the concentration effect</u>). Thus the <u>concentration of gases in the alveolus</u> is <u>diluted</u> by N_2O → <u>↓ PaO_2 & $PaCO_2$</u> → <u>hypoxia</u>. In <u>healthy individuals</u>, <u>diffusion hypoxia</u> is <u>transient</u> and may last up to <u>10 minutes</u>. At the <u>end of anesthesia</u> <u>PaO_2 may decrease 5-10 mm Hg</u> so, <u>postoperative O_2 is essential</u>.</p>	<p>N.B.;</p> <p>- Ether has a <u>much higher therapeutic ratio</u> than <u>halothane</u>, <u>enflurane</u>, or <u>isoflurane</u> so it is <u>safer</u> for use with <u>unskilled individuals</u> or from <u>un-calibrated vaporizers</u> - It can be <u>administrated</u> by • <u>Un-calibrated vaporizer</u> (Boyle's bottle). • <u>Calibrated vaporizer (EMO)</u> which is used as <u>draw-over</u> or <u>plenum vaporizers</u>. • <u>Closed circuit</u> with <u>soda lime</u>. • <u>Schimmelbusch mask</u>.</p>	<p>① It should be avoided with other <u>nephrotoxic drugs</u>. e.g. <u>aminoglycosides</u> ② <u>Enzyme Inducers</u> as <u>phenobarbitone</u>, <u>isoniazid</u> and <u>ethanol</u> → <u>↑ its metabolism</u> → <u>↑ fluoride</u>. ③ It <u>potentiates non-depolarizing muscle relaxant</u>.</p>

Halothane	Enflurane	Isoflurane	Desflurane	Sevoflurane
<ul style="list-style-type: none"> • <u>GIT: ↓GIT motility.</u> • <u>Uterus: < 0.5 % → no effect in C.S., but ↑ blood loss in therapeutic abortion.</u> > 0.5% → relax uterus → ↑ blood loss → postpartum hemorrhage. 	<ul style="list-style-type: none"> • <u>GIT: ↓GIT motility.</u> • <u>Uterus: Relaxation is dose dependent</u> 	<ul style="list-style-type: none"> • <u>GIT: ↓GIT motility.</u> • <u>Uterus: Relaxation is dose dependent.</u> 		
<ol style="list-style-type: none"> ① <u>Liver impairment.</u> ② <u>FICT.</u> ③ <u>Hypovolemic patient or severe aortic stenosis as may not tolerate ↓ABP & CO.</u> ④ <u>Pheochromocytoma as it ↑ sensitization of the heart to CAs → ↑ arrhythmias</u> ⑤ <u>Malignant hyperthermia.</u> 	<ol style="list-style-type: none"> ① <u>Renal impairment although deterioration in renal function is not likely.</u> ② <u>↑ ICT</u> ③ <u>Epileptic patients.</u> ④ <u>Malignant hyperthermia.</u> 	<p>No unique contra-indication except - Possibility of <u>coronary steal phenomenon</u> in <u>ischemic patients</u> - <u>severe hypovolemic patient.</u></p>	<ol style="list-style-type: none"> ① <u>↑ ICT</u> ② <u>Severe hypovolemic patient.</u> ③ <u>Malignant hyperthermia.</u> 	<ol style="list-style-type: none"> 1, 2, 3, as desflurane ④ <u>with soda lime in closed circuits if fresh gas flow is less than 1 L/ min.</u>
<ol style="list-style-type: none"> ① <u>Adrenaline containing local anesthetic solutions → arrhythmias so;</u> - Avoid hypoxemia and hypercapnia. - Avoid adrenaline concentration > 1: 200 000 - Avoid dosage in adult > 10 ml of 1: 100 000 in 10 min or 30 ml/hr. ② <u>β blockers and Ca⁺⁺ channel blockers → ↑ myocardial inhibition.</u> ③ <u>Aminophylline → serious ventricular arrhythmias.</u> ④ <u>It potentiates non-depolarizing muscle relaxants.</u> 	<ol style="list-style-type: none"> ① <u>Isoniazid → enzyme induction. → ↑ metabolism.</u> ② <u>It potentiates non-depolarizing muscle relaxants.</u> 	<ol style="list-style-type: none"> ① <u>It potentiates non-depolarizing muscle relaxants.</u> 	<ol style="list-style-type: none"> ① <u>It potentiates non-depolarizing muscle relaxants.</u> 	<ol style="list-style-type: none"> ① <u>It potentiates non-depolarizing muscle relaxants.</u>
<p>N.B.; The committee on safety of medicine made the following recommendations:</p> <ol style="list-style-type: none"> ① <u>A careful anesthetic history is taken to determine the previous exposure and any previous reactions to halothane.</u> ② <u>Repeated exposure to halothane within a period of 3 months should be avoided unless there are overriding clinical circumstances.</u> ③ <u>A history of unexplained jaundice or pyrexia after previous exposure to halothane is an absolute contraindication to its future use in that patient.</u> <p>N.B.; The <u>only indication</u> of halothane nowadays is <u>hypertrophic obstructive cardiomyopathy (HOCM).</u></p>			<p>N.B.; It needs a <u>special desflurane vaporizer (Tec 6)</u> as its <u>boiling point is 23.5 °C</u> so above it, <u>desflurane liquid changes to gas</u> so, the <u>vaporizer is heated electronically</u> and it has <u>electronic monitors that monitor the vaporizer's function and alarms.</u></p>	<p>N.B.; • <u>VIMA</u> is <u>volatile induction and maintenance of anesthesia</u> which is done by <u>sevoflurane.</u></p> <p>• <u>Single breath technique:</u></p> <p>It is <u>induction of anesthesia within 1-3 min</u> by <u>sevoflurane</u> via a <u>single deep maximal breath</u> with <u>4-8% in 50% O₂/N₂O</u> after <u>circuit priming with sevoflurane.</u></p>

Q: What are the properties of ideal inhalational anesthetic agents?

Inhalational Anesthetic Toxicity

I. Hepatotoxicity:

It occurs especially with halothane. It can occur also with methoxyflurane, enflurane, and isoflurane.

It is rare in pediatric patients.

Risk factors - Middle age - Obesity - Female - Exposure within 28 days.

It is of 2 types;

Type I	Type II (Halothane hepatitis)
<ul style="list-style-type: none"> - It is <u>more common</u>. - It is also reported after <u>enflurane</u> and to a <u>lesser extent</u> <u>isoflurane</u>. - <u>[C/P]</u> It is <u>transient</u> and <u>resolves</u> within a few <u>days</u> causing <u>mild changes</u> in the <u>liver</u> function tests (<u>mild dysfunction</u>) - <u>[Mechanism]</u> There is <u>increased</u> <u>glutathione-transferase</u> (<u>GST</u>) concentration due to <u>reductive</u> <u>metabolism</u> of <u>halothane</u> in <u>liver</u>. It reacts with <u>hepatic macromolecules</u> causing <u>centri-lobular tissue necrosis</u> (which is <u>worsened by hypoxia</u>). 	<ul style="list-style-type: none"> - It is <u>extremely rare</u>. - Its possibility increases on <u>repeated exposure</u> to the drug by <u>20%</u> - <u>[C/P]</u> <u>severe jaundice</u>, up to <u>fulminating hepatic necrosis</u>, with <u>high mortality</u> (<u>30-70%</u>) (<u>severe dysfunction</u>) - <u>[Mechanism]</u> <u>Hapten-protein complex</u> <u>trifluoro acetyl</u> (one of <u>halothane's oxidative</u> <u>metabolites</u>) acts as a <u>hapten (antigen)</u> causing <u>antibodies</u> against the <u>hepatocytes</u>. These <u>antibodies</u> are <u>isolated</u>.

II. Nephrotoxicity: (see also previous tables)

It can occur with methoxyflurane, enflurane, isoflurane, and sevoflurane.

Theories of nephrotoxicity

1. Traditional (Classical) Fluoride Hypothesis:

- It states that anesthetics are metabolized in the liver producing inorganic fluoride.
- When inorganic fluoride peak concentration reaches
 - > 50 mmol/L (toxic fluoride threshold), sub-clinical renal dysfunction occurs.
 - > 80 mmol/L, clinical renal dysfunction occurs.
- This hypothesis is suitable for methoxyflurane toxicity as it is very soluble so, it continues to be metabolized for some days. This causes prolonged production of fluoride ions, but peak fluoride concentration alone can not explain nephrotoxicity e.g. of sevoflurane as it does not produce renal dysfunction although its fluoride peak concentration is > 50 mmol/L.

2. Modified Fluoride Hypothesis:

- It states that the duration of plasma fluoride elevation (area under the fluoride – time curve), not just peak concentration determines nephrotoxicity.
- This hypothesis is suitable for enflurane toxicity as prolonged enflurane anesthesia causes renal dysfunction, but prolonged sevoflurane or isoflurane does not produce renal dysfunction.

3. Renal Anesthetic Metabolism Hypothesis:

- It states that intra-renal metabolism of anesthetics to fluoride or any other toxic metabolite is the cause of nephrotoxicity.
 - Intra-renal metabolism occurs by multiple cytochrome P450 (CYP) enzymes.
- Methoxyflurane is more metabolized to fluoride in the kidney than sevoflurane and enflurane.
- This is the most accepted theory nowadays.

III. Volatile Anesthetic Interaction with CO₂ Absorbents:

a. Haloalkene Nephrotoxicity:

- Halothane and sevoflurane are degraded by CO₂ absorbent. Sevoflurane is degraded into Compound A (Olefin) which is conjugated in the liver producing cysteine conjugate. The later is metabolized in the kidney of the rats by β -lyase producing nephrotoxins.
 - In human, β -lyase activity is only 10% of that in kidney of rats, therefore; no halothane or sevoflurane nephrotoxicity in human.
 - For sevoflurane, some studies are still controversial
- So, FDA recommends;

1. Avoiding the use of sevoflurane in patients with renal dysfunction.
2. Avoiding the use of fresh gas flow with sevoflurane in rates < 1 L/min or exposure should not exceed 2 MAC-hour at 1L/min.

b. Carbon Monoxide Toxicity:

Cause:

- When desflurane, enflurane or isoflurane (not with halothane or sevoflurane) are degraded by relatively dry soda lime or baralyme, carbon monoxide formation occurs causing carbon monoxide toxicity.
- The incidence increases at Monday's 1st case (or Saturday's 1st case in eastern countries) because the absorbent becomes dry by accidental leaving of continuous gas flow through an anesthetic machine over a weekend.
- Hb has 220 times greater affinity for carbon monoxide than for O₂, therefore; carbon monoxide displaces O₂ from Hb forming carboxy-Hb (CO-Hb) which may reach > 30%. This; - Decreases the ability of Hb to carry O₂.
- Shifts of O₂-Hb dissociation curve to the left causing increased Hb affinity to O₂, which decreases O₂ release to tissues.

Oxygen

Manufacture:

1. By fractional distillation of liquid air.
 2. O₂ concentrators.
- They produce O₂ from ambient air by absorption of N₂. The gas produced contains small quantities of inert gases (e.g. argon) which are harmless. They are used in;
 - Hospitals.
 - Developing countries.
 - Military surgery.
 - Long term domestic use in remote areas.

Physical characters:

- It is not flammable, but supports combustion.
- It is colorless, odorless and tasteless.
- MW 32.
- O₂ cylinders are painted black with a white shoulder. They are stored at a pressure of 137 bar at 15°C.

Physiologic effects:

See respiratory physiology

Indications:

- A. Tissue hypoxia: see causes later
- For adults, children, and infants (older than 1 month), when PaO₂ is < 60 mm Hg or SaO₂ (SpO₂) is < 90% while at rest breathing room air.

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- For neonates, when PaO_2 is < 50 mm Hg or SaO_2 (SpO_2) is $< 88\%$

B. During anesthesia

Methods of O_2 Administration:

A- Variable Performance Devices (Low Flow):

- These devices give variable O_2 concentration (FiO_2) according to;

- O_2 flow rate (adjusted by flowmeters).
- Nasopharyngeal volume (in nasal cannula).
- Patient's ventilatory pattern: Amount of air/ O_2 mixture delivered from the nasal cannula or the mask to the patient should exceed the peak inspiratory flow rate (PIFR) otherwise, rebreathing of exhaled CO_2 occurs causing low O_2 concentration.

NB. During normal breathing, $\text{PIFR} = 20\text{-}30$ L/min.

PIFR increases by increasing tidal volume (deep breathing) or increasing RR (hyperventilation).

So, the amount of air/ O_2 mixture will be variable depending on the patient's ventilatory pattern leading to variable O_2 concentrations. Therefore; no precise control of FiO_2 occurs.

- Examples:

1- Nasal Cannula (Catheter, Prongs):

- O_2 from the cannula fills the nasopharynx in between breaths so, during inspiration, O_2 is entrained from the nasopharynx into the trachea (thus mouth breathing does not affect FiO_2 as long as the communication between nasopharynx and oropharynx is patent).

- FiO_2 increases by about 1-2 % / L of O_2 delivered by the nasal cannula. It gives FiO_2 from 0.21 (at 1 L/min) up to maximum 0.4 (at $> 5\text{-}6$ L/min). FiO_2 can not be increased > 0.4 whatever O_2 flow rate is. So, O_2 flow rates > 6 L/min are not useful and when used for prolonged periods become poorly tolerated as they cause drying and crusting of the nasal mucosa.

2- Non-reservoir (Simple) Face Mask:

A 5- 6L/min O_2 flow rate is necessary to prevent rebreathing of exhaled CO_2 .

It can deliver FiO_2 from 0.3 (at 5 L/min) up to FiO_2 0.5-0.6 (figure 3-2).

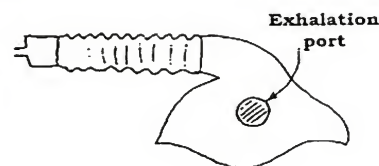


Figure 3-2; Non-Reservoir (Simple) Face Mask

3- Reservoir Masks:

a. Partially Non-rebreathing Mask:

- It is a tightly fitting face mask connected to a large volume reservoir bag.
- It contains unidirectional expiratory valve on the side of the mask to prevent entrainment of room air during inspiration and allow expiration (figure 3-3)
- This system can deliver FiO_2 0.35 (at 7 L/min) up to FiO_2 0.8-1.0 (at 15 L/min).

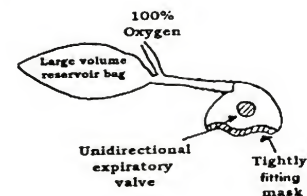


Figure 3-3 Partially Non-Rebreathing Mask

b. Non-Rebreathing Masks.

- As above but, it contains 2 unidirectional valves (figure 3-4).
- Expiratory: as above.
- Inspiratory: between the mask and the reservoir bag, to prevent entry of exhaled gas into the reservoir bag & allow inspiration.
- O_2 flow should be enough to prevent complete collapse of the bag during inspiration.
- This system can deliver FiO_2 from 0.4 (at 7 L/min) up to 1.0 (at 15 L/min).

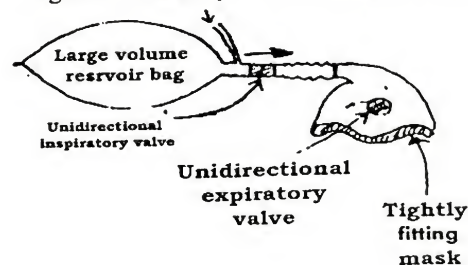


Figure 3-4 Non-Rebreathing Mask

B- Fixed-Performance Devices (High-Flow):

- These devices give a preset (fixed) O_2 concentration (FiO_2) at high flow rates by providing a sufficiently large reservoir of premixed gas. The delivered FiO_2 is not affected by changes in patient's ventilatory pattern.

- Presence of holes in the mask, entrains air with O_2 by **Bernoulli effect** as O_2 stream creates sub-atmospheric pressure which increases total air/ O_2 flow rate to exceed PIFR. So, FiO_2 becomes not dependent on Patient's ventilatory pattern. Therefore, fixed O_2 concentration is produced which depends now only on O_2 flow rate and size of holes.

- Examples:

1- Anesthesia Bag or Bag-Mask-Valve system:

- Anesthesia bags are 1-, 2-, 3-, L non-self-inflating reservoirs with a tail piece gas inlet.

- Self-inflating resuscitation bags uses a unidirectional gas flow.

- These devices can deliver FiO_2 at 1.0.

2- Air-Entrainment Venturi Mask:

- Principle : See above.

- If there is a low O_2 flow rate with wide side ports \rightarrow more amount of air will be entrained $\rightarrow \downarrow FiO_2$.

And the reverse is true, if there is a high O_2 flow rate with narrow side ports \rightarrow less amount of air will be entrained $\rightarrow \uparrow FiO_2$ (figure 3-5).

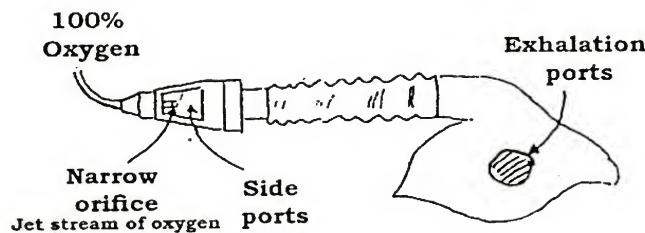


Figure 3-5 Venturi Mask

- FiO_2 can be increased by about 2% (above atmospheric $O_2 \approx 20\%$) for every one L/min O_2 flow rate.

To achieve	24%	O_2 flow rate is adjusted at 2 L/min
	28%	O_2 flow rate is adjusted at 4 L/min
	35%	O_2 flow rate is adjusted at 8 L/min
	40%	O_2 flow rate is adjusted at 10 L/min
	60%	O_2 flow rate is adjusted at 15 L/min which is enough.

- Value: to give constant FiO_2 e.g. during weaning especially in COPD patients.

N.B.; Others:

1. **Head tents or O_2 Hood:** It covers only the head and can deliver 50-80% especially in pediatrics.
2. **T-piece** connected to tracheostomy or endotracheal tube.
3. **CPAP nasal or oral face mask**
4. **B.I.P.A.P. nasal or face mask;** there is a valve which sets 2 pressure levels.

N.B.; When FiO_2 is 1.0, normal PaO_2 should be 500-600 mm Hg. To estimate the normal PaO_2 at different values of FiO_2 , we may assume that every 10% of O_2 increase PaO_2 about 50-60 mm Hg. If the FiO_2 is 0.4, the normal PaO_2 becomes 200-240 mm Hg.

Hazards (Adverse Effects) of O₂ Therapy:

1. Fires:

- O₂ supports combustion of fuels causing conflagrations or explosions.

2. Respiratory Effects:

1. Absorption Atelectasis:

- High FiO₂ can cause pulmonary atelectasis in areas distal to the site of airway closure.
- As O₂ is highly soluble in blood it replaces N₂ in the low V/Q areas causing decreased alveolar volume.

2. Hypoventilation:

In patients with COPD and chronic CO₂ retention depending on hypoxic drive from the peripheral chemoreceptors (that respond to O₂), there is loss of sensitivity of central chemoreceptors. So, High FiO₂ causes loss of peripheral chemoreceptor drive which in turn causes ventilatory failure and CO₂ narcosis.

3. Pulmonary Toxicity (Lorrain-Smith Effect):

(ARDS-like injury of the alveolar capillary membrane)

- The injury is dependent on;
 - Partial pressure of O₂ (alveolar is more important than arterial PO₂).
 - Duration of exposure.
- Although FiO₂ of 1 for up to 10-20 hours is considered safe at sea level, but FiO₂ > 0.5 for longer periods (e.g. > 30 hours) can cause toxicity.
- Mechanism: - Intracellular generation of O₂ derived free radicals.
 - Lipid peroxidation that produces lipid peroxides.

Both cause oxidation of essential enzymes which leads to cell injury.

- Pathology: Loss of synthesis of pulmonary surfactant →
- Alveolar edema → hyaline membrane, thickening of the interlobular and alveolar septa.
- Fibro-plastic proliferation.
- Absorption collapse.

C/P: Similar to adult respiratory distress syndrome.

4. Irritation to nose, pharynx and trachea:

- It causes inhibition of muco-ciliary mechanisms causing retention of secretions.

3. C.V.S. Effects:

- Vasoconstriction of peripheral, cerebral, coronary, renal and hepatic vessels (except pulmonary vessels), if PaO₂ increases > 225 mm Hg (30 Kpa).

4. Retro-lental Fibroplasia: (in neonates especially premature).

- It correlates with PaO₂ better than PAO₂ (unlike pulmonary toxicity).
- PaO₂ < 140 mm Hg is considered safe.
- Mechanism and pathology:

Increased PaO₂ causes VC. This leads to obliteration of the most immature retinal vessels. This is followed by subsequent new vessel formation at the site of damage causing proliferative retinopathy which in turn causes leakage of intravascular fluid leading to vitreo-retinal adhesions and fibrosis. Later on, retinal detachment occurs.

5. Hemopoiesis Depression:

- High FiO₂ for long time causes depression of hemopoiesis leading to anemia.

O₂ Toxicity (O₂ Free Radicals)

Introduction:

An oxygen molecule consists of 2 atoms ($O + O = O_2$). Each atom contains 8 electrons distributed as;

- Three inner orbitals containing paired electrons spinning in opposite directions ($3 \times 2 = 6$ electrons).
- Two outer most orbitals of the oxygen atom containing unpaired electrons spinning in the same direction (2 electrons) (figure 3-6).

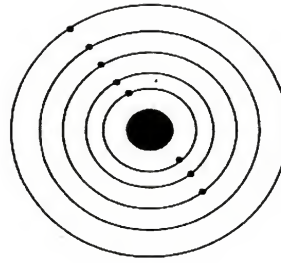


Figure 3-6; O₂ atom

Free Radical:

It is an atom or molecule that has one or more unpaired electrons in its outer orbitals.

(Free means that the molecule or the atom is capable of independent existence or free living).

Free radicals tend to be highly reactive species because of their unpaired electrons → high oxidant activity.

Oxygen is a free radical, but it is not highly reactive (weak oxidizing agent) because the two unpaired electrons spin in the same direction.

Types of O₂ Free Radicals:

1. Super-oxide radical (O_2^{\bullet}).
2. Hydrogen peroxide (H_2O_2): It is not a free radical, but it gives powerful cytotoxic compounds.
3. Hydroxyl radical ($^{\bullet}OH$).
4. Nitric oxide (NO).
5. Carbon monoxide (CO).

N.B.; $N_2O \rightarrow$ Nitrous oxide.
 $NO_2 \rightarrow$ Nitrogen dioxide.

NO \rightarrow Nitric oxide.
 $N_2 \rightarrow$ Nitrogen.

Pathological Effects (Free Radical Reactions):

A- Cellular Injury:

- They increase cell membrane permeability to ions and cause loss of its integrity (**lipid peroxidation**).
- They affect DNA by causing chromosomal deletion, mutations, and cell death.

B- Tissue Damage: as;

- Carcinogenesis.
- Immunologic and Inflammatory disorders e.g. ARDS.
- Aging and Atherosclerosis.
- Retinopathy of prematurity.
- Reperfusion injury of transplanted organs.

Management:

A. Prevention:

1. FiO₂:

- Avoid $FiO_2 > 0.6$ as it is accompanied with high risk of O₂ toxicity.

So, if O₂ is used $> 60\%$, it should not be used for $> 2-3$ days (in ICU).

If O₂ is used $< 60\%$, O₂ toxicity still can occur especially when the defense mechanisms are impaired.

N.B.; The optimal FiO_2 is the lowest $FiO_2 (< 0.6)$ which the patient can tolerate.

PHARMACOLOGY OF ANESTHESIA**2. Antioxidant status:**

By assessing levels of selenium, vitamins A, C & E in serum So, any deficiency can be replaced.

B. Curative: By Antioxidant drugs (Free Radical Scavengers).

1- **Vitamins A, C, E and Selenium.**

2- **Aminosteroids: Lazaroids e.g.: Tirilizad**

Advantage: • 100 times more potent than methyl prednisolone.

• It has no side effects of methyl prednisolone.

Mechanism: It inhibits lipid peroxidation so, acts as an antioxidant.

3- **Glucocorticoids (Methyl prednisolone)**

It is effective in acute spinal cord injury, if given within 8 hours.

By - Inhibition of lipid peroxidation.

- Scavenging O_2 derived free radicals.

Dose: High: 30 mg / Kg i.v. (mega dose).

4. **N-acetyl cysteine:**

- It is a popular mucolytic agent.

- It is used as an antioxidant.

5) **Others:**

1- Desferrioxamine: It chelates Fe^{++} causing inhibition of OH formation.

2- Xanthine oxidase inhibitors e.g. Allopurinol.

Carbon Dioxide (CO_2)

Manufacture:

- 1- As a byproduct of fermentation in brewing of beer.
- 2- As a byproduct of manufacture of hydrogen.
- 3- By heating Mg and Ca carbonate in presence of their oxides.
- 4- As a combustion gas from burning fuel.

CO_2 cylinders:

- Grey cylinders containing liquid CO_2 at 50 bar pressure.
- The filling ratio is 0.75 and the liquid phase occupies about 90-95% of the cylinder.

Physical Characters: - Colorless and with pungent odor.

- M.W. 44, critical temperature $31^\circ C$, critical pressure 73.8 bar.

Physiologic effects:

1. Respiration: (see respiratory physiology)

- CO_2 increases rate and depth of respiration. It acts directly and reflexly via chemoreceptors. This effect is maximal at 5-7%.

- CO_2 has expectorant action as it liquefies sputum.

2. C.V.S:

It produces changes similar to those induced by pain or light anesthesia.

a. CO, ABP & HR: (\uparrow then > 75 mm Hg \downarrow)

- **Biphasic response** i.e. Increased $PaCO_2$ (up to 75mm Hg) causes progressive increase in CO, ABP, and HR due to indirect sympathetic stimulation.

$PaCO_2 > 75$ mm Hg causes decrease in CO, ABP, and HR due to direct myocardial depression.

b. Skin, cerebral, coronary and GIT vessels (not pulmonary vessels).

Increased $PaCO_2$ causes vasodilatation.

3. C.N.S:

- Low levels depress the excitability of cerebral cortex.

- High levels activate sub-cortical centers causing convulsions.

- Higher levels cause depression of CNS.

4. GIT:

- It produces irritant effect on GIT mucosa leading to increase its secretions (and HCl).

Therapeutic uses: used by special CO₂ flowmeters (5-7% CO₂ in O₂).

Nowadays, the use of CO₂ is decreased in anesthesia due to its risks;

- 1- It increases the speed of induction and recovery from inhalational anesthesia as it increases the respiratory minute volume.
- 2- It facilitates blind nasal intubations as it increases ventilation.
- 3- To assist in reinstitution of spontaneous ventilation after a period of artificial hyperventilation.

Toxicity of CO₂ (Retention of CO₂):

- It is most common in patients with chronic emphysema who no longer respond to the normal respiratory effect of alveolar CO₂ or if it is accidentally administered.

- C/P: CO₂ accumulation → Respiratory acidosis.

- Treatment: 1- IPPV.

2- Tolatrol; Tri hydroxyl-methyl amino methane (THAM)

- It is an amine buffer that acts as a proton acceptor.

- It unites with carbonic acid resulting in formation of bicarbonate.

Helium

Physical characters:

- It is an inert gas.

- It has low density = 0.16

(density of O₂ = 1.3)

Effects:

- Mixtures of helium (80%) & O₂ (20%) can be inhaled to decrease the work of breathing & enable O₂ to pass via the obstructed passages with the least effort e.g. upper respiratory tract obstruction or status asthmaticus.

- Because during obstruction, the flow becomes turbulent so, using a gas mixture with low density decreases turbulence & may change flow to laminar. This produces more easier diffusion of the gas mixture. N.B.; Turbulent flow (Reynolds' number) \propto density.

INTRAVENOUS **ANESTHETIC AGENTS**

Pharmacokinetic of Intravenous Anesthetics:

Absorption:

- I.v. route completely bypasses the process of absorption as drugs are placed directly into the blood.

Distribution:

- After i.v. injection, the drug is distributed to different tissues according to their blood supply. Type of tissues are discussed before.

- Distribution into muscles (lean) is slower due to their low lipid content, but is quantitatively important due to their relatively good blood supply and large mass.

PHARMACOLOGY OF ANESTHESIA

- Distribution into fat is slow despite its high lipid content due to its poor blood supply. Fat contributes little to the initial redistribution or termination of action of i.v. anesthetic agents, but fat depots contain a large proportion of the injected dose.
- After the highly perfused organs (heart, kidney, brain, and liver) are saturated during initial distribution, the greater mass of the less perfused organs will continue to take up the drug from the blood. As plasma concentration falls, some drug leave the highly perfused organs to maintain equilibrium according to the concentration gradient. This redistribution from the vessel-rich group is responsible for termination of effect of many i.v. anesthetic agents. e.g. wakening from effects of thiopentone is not due to metabolism or excretion but rather to redistribution of drug from brain to muscle.
- On repeated doses of drug, saturation of less perfused organs occurs therefore, redistribution can not occur and awakening will depend to a greater extent upon drug elimination so, rapid-acting drugs such as thiopentone and fentanyl will become longer acting after repeated administration or when a large single dose is given.

Biotransformation (Metabolism):

- The liver is the primary organ of metabolism.
- If metabolism is rapid (indicated by a short elimination half life), it may contribute to some extent to the recovery of consciousness.
- Due to the large distribution volume of i.v. anesthetic drugs, total elimination takes many hours or days.

Excretion:

- Mainly to end water-soluble metabolites.
- Only a small % of drugs are excreted unchanged in the urine.

Structure Activity Relationship of Barbiturates

- ① At position 1, substitution by methyl group → shorter duration of action.
→ convulsion & excitatory phenomenon

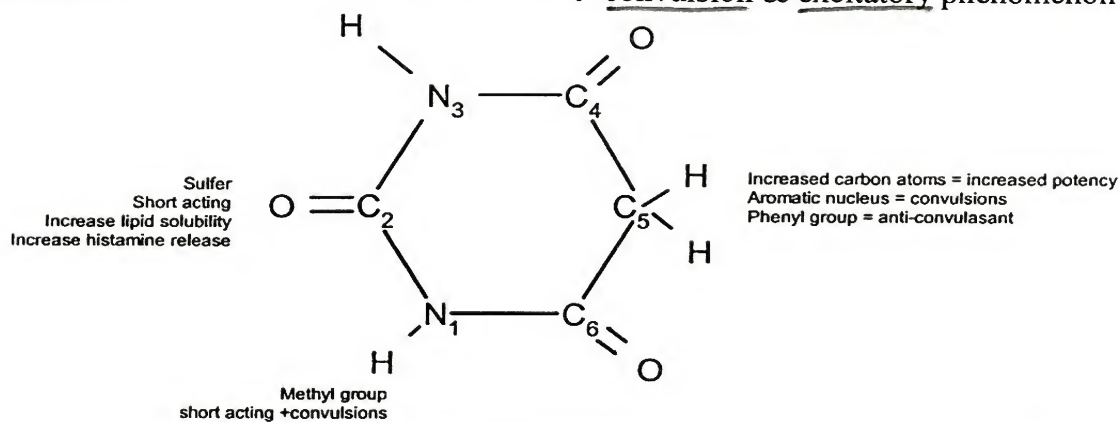


Figure 3-7; Barbituric acid

- ② At position 2, substitution by sulfur atom → shorter duration of action.
→ ↑ lipid solubility.
→ ↑ histamine release.

- ③ At position 5,

- ↑ carbon atoms in side chains → ↑ potency.
- Presence of aromatic nucleus in an alkyl group → convulsant properties.
- Presence of phenyl group → anticonvulsant properties (figure 3-7).

Example	Position 1	Position 2	Characters
Oxy-barbiturates	H	O	Delayed onset and prolonged action
Methyl-barbiturates	CH ₃	O	Rapid onset and recovery + Excitatory phenomenon (CH ₃)
Thio-barbiturates	H	S	Rapid onset and recovery
Methyl thio-barbiturates	CH ₃	S	Very rapid onset and recovery (CH ₃ +S) + excitatory phenomenon.

Intravenous Anesthetic Agents include:

- 1- Thiopentone sodium; Thio-barbiturates.
- 2- Methohexitone sodium; Methyl-barbiturates.
- 3- Propofol; Di-isopropyl phenol.
- 4- Etomidate; Carboxylated imidazole compound.
- 5- Ketamine; Phencyclidine derivatives

Other i.v. agents used in anesthesia:

- Benzodiazepines.
- Opioids.
- Neuroleptic agents.

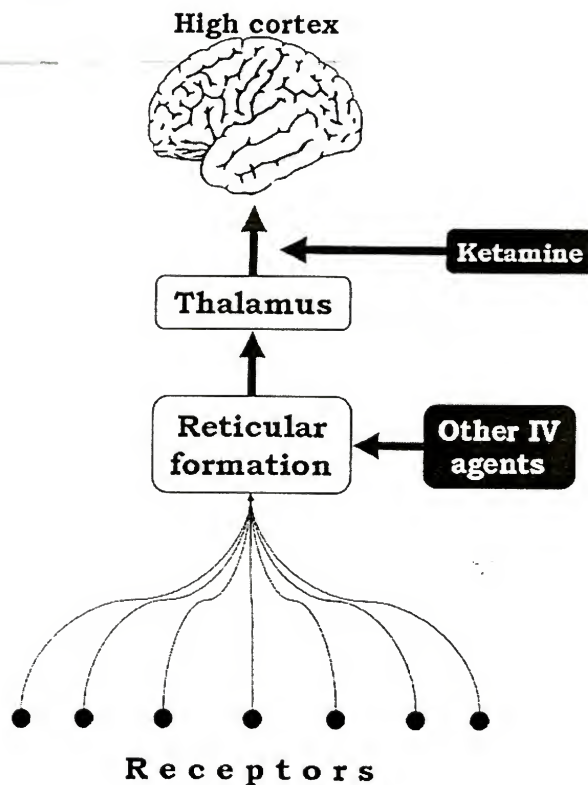
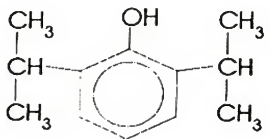
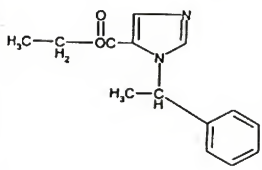
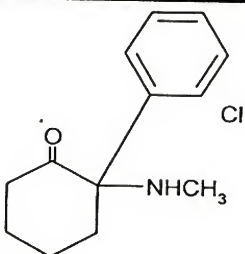


Figure 3-8; Site of action of intravenous anesthetics

PHARMACOLOGY OF ANESTHESIA

	Thiopentone Sodium	Methohexitone Sodium
Chemical Structure		
Physical properties	<p>- <u>pKa 7.6</u> - <u>pH 10.8</u> - <u>Lipid soluble</u> (so, it <u>crosses BBB</u>) - <u>Short shelf life</u>. - Stored in <u>nitrogen</u> (to prevent chemical reaction with atmospheric <u>CO₂</u>) and mixed with <u>6% anhydrous Na carbonate</u> (to ↑ its water solubility). - <u>Yellowish powder</u> with a <u>bitter taste</u> and <u>faint smell</u> of garlic. - <u>Vial; 500 or 1000 mg</u>. - <u>Freshly</u> prepared solution is <u>stable for 2 weeks</u>, but manufacturers recommend <u>storing for 24 hrs only</u> as it contains <u>no antibacterial preservatives</u>.</p>	<p>- <u>pKa 7.9</u> - <u>pH 11.1</u> - <u>Less lipid soluble</u> (than thiopentone) - <u>Short shelf life</u>. - Stored in <u>6% anhydrous Na carbonate</u> (to ↑ its water solubility). - <u>White powder</u>. - <u>Vial; 100 or 500 mg</u>. - <u>Freshly</u> prepared solution is <u>stable for 6 weeks</u>, but manufacturers recommend <u>storing for 24 hrs only</u> as it contains <u>no antibacterial preservatives</u>.</p>
Dose	<p>① <u>I.v.: (2.5% solution i.e. 25 mg/mL)</u> - For induction: <u>3-6 mg/Kg</u> - For sedation: <u>0.5 - 1.5 mg/kg</u> The dose varies according to the <u>patient's response</u>. So in <u>healthy adults</u> initial <u>4 mg/Kg</u> over <u>15 sec</u> is given, if loss of eye lash does not occur within 30 sec. <u>Additional</u> doses of <u>50-100 mg</u> are given <u>slowly</u> till <u>loss of consciousness</u> occurs (may 1st only 2 mL is given initially and ask the patient if any pain to avoid inadvertent intra-arterial injections). In <u>young children</u> <u>6 mg/Kg</u>. In <u>elderly</u> <u>2.5-3 mg/kg</u>. ② <u>Rectal: (5-10% solution)</u> <u>30-44 mg/kg</u> - To induce <u>basal narcosis (sleep)</u> in <u>children</u> within <u>10-15 min</u>. - It may be used to sedate <u>un-cooperative children</u> before anesthesia, but may → <u>loss of airway control</u>.</p>	<p>① <u>I.v.: (1% solution i.e. 10 mg/mL)</u> - For induction <u>1-1.5 mg/kg</u> - For sedation <u>0.2 - 0.4 mg/Kg</u> - <u>↓ dose</u> in <u>infant & elderly</u>. ② <u>I.m.: 6.6 mg/Kg</u>. ③ <u>Rectal: 20-25 mg/kg</u>. The <u>same as thiopentone</u>.</p>
Pharmacokinetic Distribution	<p>① <u>Recovery</u> of consciousness (duration) due to <u>redistribution</u> only. <u>Metabolism</u> is responsible for <u>end of drowsiness</u> which may persist for <u>hours (24-36 hrs)</u>. ② <u>Protein binding</u> <u>80%</u> ③ <u>Non-ionized fraction</u> at <u>physiologic pH</u> <u>60%</u> ④ <u>Elimination half life</u> <u>11.5 hrs</u> ⑤ <u>More lipid soluble</u>.</p>	<p>① <u>Recovery</u> of consciousness due to <u>redistribution</u> only. <u>Metabolism</u> is responsible for <u>end of drowsiness</u> which may persist for <u>hours</u>. ② <u>Protein binding</u> <u>80%</u> ③ <u>Non-ionized fraction</u> <u>75%</u> ④ <u>Half life</u> <u>4 hrs</u>. ⑤ <u>Less lipid soluble</u> (than thiopentone).</p>
Metabolism	<p>- In the <u>liver</u> by hepatic <u>oxidation</u> to inactive <u>water-soluble</u> metabolites (<u>more slow</u> than methohexitone) → <u>prolonged drowsiness</u> and <u>disturbed psychomotor</u> function up to <u>24-36 hrs</u>. - <u>Hangover effect & cumulation (++)</u> if <u>further doses</u> are given within <u>24-48 hrs</u> especially in <u>Elderly patients</u>. • <u>Obese</u> patients as <u>doses</u> should be based on <u>lean body mass</u> as <u>fat distribution</u> is low, however, <u>elimination</u> may be delayed due to <u>↑ retention of drug by fat</u>.</p>	<p>- In the <u>liver</u> by hepatic <u>oxidation</u> to inactive <u>water soluble</u> metabolites, but it is <u>cleared</u> by the <u>liver</u> <u>3-4 times</u> more <u>rapid</u> than thiopentone which is responsible for its <u>recovery</u> from <u>drowsiness</u> and <u>disturbed psychomotor function</u>. - <u>Cumulation (+)</u> <u>Less than thiopentone</u>.</p>
Excretion	<p>- Mainly as <u>inactive water soluble</u> metabolites in the <u>urine</u>. - <u>Small %</u> is excreted <u>unchanged in the urine</u>.</p>	<p>- Mainly as <u>water soluble end metabolites</u> in the <u>urine</u>. - <u>Small %</u> is excreted <u>unchanged in feces</u>.</p>

N.B.; pKa: It is the pH at which the compound is at equilibrium between dissociation (ionized) and un-dissociation (unionized)

Propofol	Etomidate	Ketamine HCl
		
<ul style="list-style-type: none"> - <u>Highly lipid soluble</u> (not water soluble) - <u>Long shelf life.</u> - <u>In the past</u>, it was formulated in <u>Cremophor EI</u> which → <u>histamine release</u> & <u>↑ anaphylactoid reaction</u> and potentiates muscle relaxant. Now, it is <u>white aqueous oil in water emulsion</u> containing <u>soya bean oil</u> & <u>purified egg phosphatide (egg lecithin)</u>. - <u>Ampoules: 20mL (10mg/mL) (1%)</u> - It should be <u>used completely</u> within <u>6 hrs</u> of opening the ampoules with <u>good sterile techniques</u> because it contains <u>no antibacterial preservatives</u>. 	<ul style="list-style-type: none"> - <u>Water soluble</u> (but <u>not stable</u> with it). - <u>Long shelf life.</u> - <u>Clear aqueous solution</u> containing <u>35% propylene glycol</u>. - <u>Ampoules: 10 mL (2mg/mL)</u> i.e. ampoule contains <u>20 mg</u>. 	<ul style="list-style-type: none"> - <u>pKa 7.5</u> - <u>pH 3.5 – 5.5</u> - <u>Extremely lipid soluble</u> (also <u>water soluble</u>). - <u>Long shelf life.</u> - <u>Clear solution</u> containing <u>NaCl</u> to be <u>isotonic</u>. - <u>Multi-dose vials: 10mL (50-100 mg/ mL)</u>. - It contains <u>benzethonium chloride 0.1 mg/mL</u> as a <u>preservative</u>.
<p>① <u>I.v.:</u> (1% solution i.e. 10 mg/mL)</p> <ul style="list-style-type: none"> - For <u>induction: 1.5 – 2.5 mg/kg</u> ↓ dose in <u>elderly</u> and <u>premedicated</u> patient. ↑ dose in <u>children 3 - 3.5 mg/kg</u>. (not recommended for <u>children < 3 years</u>) <p>② <u>I.v. infusion:</u></p> <ul style="list-style-type: none"> - For <u>maintenance: multi-step infusion</u> regimen. 10 mg/kg/hr for the <u>1st 10 min.</u> 8 mg/kg/hr for the <u>2nd 10 min.</u> 6 mg/kg/hr for the <u>remaining time.</u> - For <u>sedation: 2-4 mg/kg/hr</u> e.g. during <u>regional anesthesia</u> or <u>endoscopy</u> or in <u>ICU</u>. 	<p>① <u>I.v.</u></p> <ul style="list-style-type: none"> - For <u>induction 0.2 – 0.3 mg/Kg.</u> 	<p>① <u>I.v.:</u></p> <ul style="list-style-type: none"> - For <u>induction: 1-2 mg/kg</u> ↓ dose in <u>elderly</u> & <u>shocked</u> patients. <u>Additional doses</u> are needed <u>1-1.5 mg/kg</u> every <u>5-10 min.</u> - For <u>analgesia (without loss of consciousness)</u> <u>0.25 – 0.5 mg/kg</u> or <u>50µg/kg/min.</u> <p>② <u>I.m.:</u> <u>5-10 mg/kg.</u></p> <p>③ <u>Oral:</u> <u>5-10 mg/kg.</u></p>
<p>① <u>Recovery of consciousness</u> due to <u>redistribution & detoxification.</u></p> <p>② <u>Half life 3- 4.8 hr.</u></p> <p>③ <u>effective half life 30-60 min.</u></p> <p>④ <u>Highly lipid soluble.</u></p>	<p>① <u>Recovery of consciousness</u> due to <u>redistribution.</u></p> <p>② <u>Protein binding</u> <u>76%</u></p> <p>③ <u>Non-ionized fraction: large</u></p> <p>④ <u>Half life 75 min</u></p> <p>⑤ <u>Highly lipid soluble</u></p>	<p>① <u>Recovery of consciousness</u> due to <u>redistribution.</u></p> <p>② <u>Protein binding</u> <u>12%</u></p> <p>③ <u>Non-ionized fraction</u> <u>60%</u></p> <p>④ <u>Half life</u> <u>2.5 hrs</u></p> <p>⑤ <u>Highly lipid soluble</u></p>
<ul style="list-style-type: none"> - In the <u>liver</u> & in <u>extra-hepatic sites</u> by <u>conjugation</u> → <u>inactive water soluble metabolites</u> it is <u>rapid (10 times)</u> more than <u>thiopentone</u> → <u>rapid recovery</u> after <u>continuous infusion.</u> 	<ul style="list-style-type: none"> - In the <u>liver</u> (hepatic <u>microsomal enzymes</u>) & in <u>plasma (esterase)</u> by <u>hydrolysis</u> → <u>inactive water soluble metabolites.</u> 	<ul style="list-style-type: none"> - In the <u>liver</u> by <u>demethylation</u> and <u>hydroxylation</u> → <ul style="list-style-type: none"> • <u>Active nor-ketamine</u> • <u>Other inactive metabolites</u> <u>Induction</u> of <u>hepatic enzymes</u> may partially explain the development of <u>tolerance</u> in patients who receive <u>multiple doses of ketamine.</u>
<ul style="list-style-type: none"> - <u>Cumulation:</u> <u>No</u> 	<ul style="list-style-type: none"> - <u>Cumulation:</u> <u>No</u> 	<ul style="list-style-type: none"> - <u>Cumulation:</u> <u>No</u>
<ul style="list-style-type: none"> - Mainly as <u>inactive water soluble metabolites</u> in the <u>urine</u> <u>0.3%</u> is excreted <u>unchanged</u> in the <u>urine.</u> 	<ul style="list-style-type: none"> - Mainly as <u>inactive water soluble metabolites</u> in the <u>urine</u> <u>2%</u> is excreted <u>unchanged</u> in the <u>urine</u> 	<ul style="list-style-type: none"> - Mainly as <u>water soluble metabolites</u> in the <u>urine.</u> <u>2.5%</u> is excreted <u>unchanged</u> in the <u>urine.</u>

PHARMACOLOGY OF ANESTHESIA

	Thiopentone sodium	Methohexitone sodium
Pharmacological Action 1. CNS CMR Cerebral Metabolic Rate. CBF Cerebral Blood Flow ICP Intracerebral Pressure. CPP Cerebral Perfusion Pressure. ABP Arterial Blood Pressure.	<p>- Mechanism of action: It depresses the reticular formation in the brainstem by ↑ transmission of inhibitory neurotransmitter (γ amino-butyric acid) (GABA) → unconsciousness.</p> <p>① CNS depression: ranging from mild sedation to unconsciousness. Onset < 30 sec. after i.v. route depending on loss of eye lash reflex Recovery occurs within 5-10 min.</p> <p>② Potent anticonvulsant effect: EEG changes range from low voltage fast activity (with the small doses) to high voltage slow activity & electrical suppression (with the very large doses).</p> <p>③ Poor analgesic effect: It has antanalgesic effect (by ↓ pain threshold) which occurs at sub-anesthetic blood concentrations i.e. at low doses or during recovery → restlessness in postoperative period.</p> <p>④ ↓CMR → ↓ cerebral O₂ consumption (up to 50%) → 2ry VC of cerebral vessels → ↓ CBF & ICP CPP is ↑ because the ↓ ICP exceeds the ↓ in ABP. CPP = Cerebral arterial pressure – (Cerebral venous pressure + ICP). So, it provides brain protection from transient episodes of focal ischemia e.g. cerebral embolism, but not from global ischemia e.g. cardiac arrest.</p> <p>⑤ No postoperative nausea and vomiting. ⑥ No excitatory or emergence phenomenon.</p>	<p>- Mechanism of action: As thiopentone</p> <p>① CNS depression: Onset 15-20 sec. after i.v. Recovery occurs within 2-3 min. More rapid onset and recovery than thiopentone.</p> <p>② Anticonvulsant effect: EEG changes as thiopentone, but epileptic form activity may occur in epileptic patients.</p> <p>③ Poor analgesic effect: Antanalgesic effect.</p> <p>④ ↓CMR as thiopentone.</p>
2. Respiratory system	<p>① Respiratory depression: - More in premedicated patients especially with opioids (may need assisted mechanical ventilation). - ↓ ventilatory drive to hypercapnia and hypoxia due to ↓ sensitivity of respiratory center. - Short period of apnea frequently preceded by few deep breaths. - RR & T.V ↓ (but ↑ with surgical stimulation).</p> <p>② Bronchial muscle tone ↑ up to bronchospasm especially in asthmatic patients due to presence of sulfur atom.</p> <p>③ Laryngeal spasm precipitated by surgical stimulation, secretions, foreign bodies (or pharyngeal airway or laryngeal mask) in the region of the pharynx or larynx because thiopentone depresses parasympathetic laryngeal reflexes to a lesser extent than other areas in CNS.</p>	<p>① Respiratory depression: As thiopentone</p> <p>② Bronchial muscle: no effect</p> <p>③ Laryngeal spasm More than thiopentone.</p>
3. CVS VM center = Vasomotor center	<p>① ABP: ↓↓ Due to VM center depression → (↓ myocardial contractility i.e. negative inotropic action & peripheral VD) especially with large doses or rapid injection.</p> <p>② HR: ↓ but, reflex tachycardia occurs due to baroreceptor inhibition caused by hypotension & by loss of vagal tone.</p> <p>③ CO: is maintained because inhibition of baroreceptor reflex → VC of resistant vessels → slight ↑ ABP Reflex tachycardia N.B.: In absence of adequate baroreceptor reflex e.g. hypovolemia, congestive heart failure, β adrenergic blockade, constrictive pericarditis, cardiac valve stenosis, previously uncontrolled hypertensive patients, or old age → Profound ↓ ABP & ↓ CO</p>	As thiopentone With <u>less hypotension</u>
4. Neuro-muscular effect	<p>- ↓ muscle tone at high blood concentrations due to inhibition of spinal cord reflexes. - Muscle movement in response to surgical stimulation is common.</p>	As thiopentone
Others	<p>① Renal: ↓ renal blood flow → ↓ GFR (in proportion to ↓ ABP).</p> <p>② Hepatic: ↓ hepatic blood flow. - It causes induction of hepatic enzymes → ↑ rate of metabolism of some drugs as digitalis, steroids, oral anticoagulants, oral contraceptives, and phenytoin. - It combines with cytochrome P-450 enzyme system → interference with metabolism of other drugs e.g. tricyclic antidepressants.</p> <p>③ Eye: ↓ intraocular pressure.</p>	As thiopentone.

Propofol	Etomidate	Ketamine HCl
<p>- Mechanism of action: As <u>thiopentone</u></p> <p>① <u>CNS depression</u>: ranging from... Onset 20-40 sec after i.v. depending on loss of verbal contact as transfer from blood to brain is slower than with thiopentone → a delayed loss of eyelash reflex so, over dosage may occur if this clinical sign is used. Recovery is rapid.</p> <p>② <u>No anticonvulsant effect</u>: It ↓ duration of seizures induced by ECT in humans. It ↓ frequency & ↑ amplitude in EEG. Care with epileptic patients as reports of convulsion occur after its use.</p> <p>③ <u>Poor analgesic effect</u> and <u>no antanalgesic effect</u>.</p> <p>④ <u>↓CMR → ↓CBF & ↓ICP</u> It may cause critical ↓ in CPP < 50 mmHg, but it provides some degree of cerebral protection during focal ischemia as thiopentone.</p> <p>⑤ <u>Anti-emetic and anti-pruritic action</u>: It is a unique characteristic of it.</p> <p>⑥ <u>Excitatory phenomenon (+)</u></p>	<p>- Mechanism of action: It <u>depresses the reticular formation</u>. Unlike barbiturates, it may have <u>dis-inhibitory effect</u> on parts of CNS that control <u>extra-pyramidal motor activity</u> → 30-60% incidence of <u>excitatory phenomenon</u>.</p> <p>① <u>CNS depression</u>: Onset <u>rapid</u> Recovery <u>2-3 min</u>.</p> <p>② <u>EEG changes</u> as those associated with barbiturates, but it enhances <u>somato-sensory evoked potentials</u>.</p> <p>③ <u>Very poor analgesic effect</u> Antanalgesic effect is <u>unknown</u>.</p> <p>④ <u>↓CMR → ↓CBF & ↓ICP</u> (to the same degree as thiopentone). CPP is well maintained due to <u>minimal C.V.</u> effects, but it is <u>not used in brain protection</u> due to the <u>neuro-toxic effect of propylene glycol</u>.</p> <p>⑤ It causes <u>postoperative nausea and vomiting</u>.</p> <p>⑥ <u>Excitatory phenomenon (+++)</u> <u>Emergence phenomenon (+)</u></p>	<p>- Mechanism of action: It produces <u>dissociative anesthesia</u> (rather than depression of reticular activating system) i.e. it functionally <u>dissociates the thalamus</u> (which relays <u>sensory impulses</u> from the reticular activating system to the cerebral cortex) from the <u>limbic cortex</u> (which is involved with the <u>awareness of sensation</u>) while some <u>brain neurons</u> are <u>inhibited</u>, others are <u>excited</u>. Clinically, patients appear <u>conscious</u> e.g. <u>eye opening, swallowing, muscle contracture</u>, but <u>unable to process or respond to sensory input</u> (figure 3-8). It also blocks <u>N-methyl D-aspartate receptors</u>.</p> <p>① <u>CNS (+)</u> Onset is slow 30-60 sec after i.v. 3-4 min after i.m. Recovery is slow 10-15 min after i.v. 15-25 min after i.m.</p> <p>② <u>EEG changes</u>: <u>Loss of alpha rhythm</u> and <u>predominant theta activity</u>.</p> <p>③ <u>Potent analgesic effect</u> (somatic) at sub-anesthetic blood level. <u>No antanalgesic effect</u></p> <p>④ <u>↑CMR → ↑cerebral O₂ consumption</u> and <u>↑CBF & ↑ICP</u> so, it has a <u>harmful effect</u> on patients with <u>space occupying lesions (no brain protection)</u></p> <p>⑤ <u>Postoperative nausea and vomiting</u></p> <p>⑥ <u>Emergence phenomenon (++)</u> <u>Excitatory phenomenon (+)</u></p> <p>① <u>Respiration is maintained or slightly ↑</u> (unless high doses are given) Ventilatory drive is <u>minimally affected</u> with ordinary doses. Apnea may occur <u>especially</u> with patients premedicated with <u>opioids</u>.</p> <p>② <u>Bronchial muscle tone ↓ → potent bronchodilatation</u>.</p> <p>③ <u>Pharyngeal & Laryngeal reflexes</u> and patient's airway are <u>maintained</u>, but their presence can <u>not be guaranteed</u>.</p> <p>① <u>ABP: ↑ up to 20%</u> ② <u>HR: ↑ up to 20%</u> ③ <u>CO: ↑</u> Due to <u>central stimulation of sympathetic system</u> → +ve inotropic effect ↑ <u>myocardial sensitivity to catecholamines</u>. (although ketamine has <u>direct myocardial depressant action in vitro</u>). This sympathetic stimulation <u>increases cardiac work</u> → ↑ cardiac O₂ consumption So, it is <u>avoided</u> in patients with; • <u>Coronary artery disease</u>. • <u>Uncontrolled hypertension</u>. • <u>Congestive heart failure</u>.</p> <p>- ↑ muscle tone. - Spontaneous movement may occur, but reflex movement to surgery is <u>uncommon</u>.</p> <p>① <u>Uterus</u>: It <u>crosses placenta</u> readily, so fetal concentration is nearly equal to that of the mother.</p> <p>② <u>Eye: Transient ↑ IOP</u> Eye movement often <u>persists</u> during surgical anesthesia stage.</p> <p>③ <u>↑ salivation</u> so, patients are premedicated with <u>anticholinergic drugs</u>.</p>
<p>① <u>Respiratory depression</u>: as thiopentone with <u>longer periods of apnea</u>.</p> <p>② <u>Bronchial muscles</u>: No effect</p> <p>③ <u>Laryngeal spasm is uncommon</u> It depresses upper airway reflexes (more than thiopentone) so, it is the <u>drug of choice</u> with <u>laryngeal masks</u>.</p>	<p>① <u>Respiratory depression</u>: Less than other agents (no apnea)</p> <p>② <u>Bronchial muscle</u>: no effect</p>	<p>① <u>Respiration is maintained or slightly ↑</u> (unless high doses are given) Ventilatory drive is <u>minimally affected</u> with ordinary doses. Apnea may occur <u>especially</u> with patients premedicated with <u>opioids</u>.</p> <p>② <u>Bronchial muscle tone ↓ → potent bronchodilatation</u>.</p> <p>③ <u>Pharyngeal & Laryngeal reflexes</u> and patient's airway are <u>maintained</u>, but their presence can <u>not be guaranteed</u>.</p>
<p>① <u>ABP: ↓↓↓ up to 40%</u> (more than thiopentone) due to • <u>Peripheral VD</u> (mainly) • <u>↓ myocardial contractility</u>. N.B.; pressor response to <u>tracheal intubation</u> is <u>attenuated</u> to a <u>greater degree</u> than with thiopentone.</p> <p>② <u>HR: Slight ↑ or no effect</u> as it <u>abolishes the baroreceptor reflex</u>.</p> <p>③ <u>CO: is maintained</u>as thiopentone</p>	<p>① <u>ABP: slight ↓</u> Due to slight peripheral VD (no effect on myocardial contractility)</p> <p>② <u>HR: No effect</u></p> <p>③ <u>CO: No effect</u> It is the <u>least agent which affects the C.V.S.</u></p>	<p>① <u>ABP: ↑ up to 20%</u> ② <u>HR: ↑ up to 20%</u> ③ <u>CO: ↑</u> Due to <u>central stimulation of sympathetic system</u> → +ve inotropic effect ↑ <u>myocardial sensitivity to catecholamines</u>. (although ketamine has <u>direct myocardial depressant action in vitro</u>). This sympathetic stimulation <u>increases cardiac work</u> → ↑ cardiac O₂ consumption So, it is <u>avoided</u> in patients with; • <u>Coronary artery disease</u>. • <u>Uncontrolled hypertension</u>. • <u>Congestive heart failure</u>.</p>
<p>-As thiopentone</p>	<p>-As thiopentone</p>	<p>- ↑ muscle tone. - Spontaneous movement may occur, but reflex movement to surgery is <u>uncommon</u>.</p>
<p>① <u>Renal: transient ↓ in renal blood flow</u>.</p> <p>② <u>Hepatic: ↓ hepatic blood flow</u> No change in <u>liver function tests</u> (after its infusion for 24 hrs).</p> <p>③ <u>Endocrine</u>: ↓ <u>Plasma concentration of cortisol</u>.</p>	<p>① <u>Endocrine</u>: - After <u>single induction dose</u> → ↓ <u>cortisol and aldosterone synthesis</u> by <u>inhibition of enzymes</u> in <u>adrenal glands</u>. - After <u>long term infusions</u> → <u>adreno-cortical suppression</u> i.e. it <u>impairs the response to adreno-cortico-trophic hormone</u> → ↑ <u>infections and mortality</u> in <u>critically ill patients</u>.</p>	<p>① <u>Uterus</u>: It <u>crosses placenta</u> readily, so fetal concentration is nearly equal to that of the mother.</p> <p>② <u>Eye: Transient ↑ IOP</u> Eye movement often <u>persists</u> during surgical anesthesia stage.</p> <p>③ <u>↑ salivation</u> so, patients are premedicated with <u>anticholinergic drugs</u>.</p>

PHARMACOLOGY OF ANESTHESIA

	Thiopentone sodium	Methohexitone sodium
Adverse effects	<p>① <u>CNS</u>:</p> <ul style="list-style-type: none"> - <u>Drowsiness</u> persists for 24-36 hrs. - <u>Excitatory phenomenon</u> on induction is <u>absent</u> (-) & <u>Emergence phenomenon</u> on emergence is <u>absent</u> (-) ② <u>Respiratory depression</u>, bronchospasm, laryngospasm. ③ <u>CVS depression</u>, profound ↓ ABP & CO in..... ④ <u>During injection</u>: a) <u>I.v. injections</u> (2.5% solution) <u>Pain</u> and <u>thrombophlebitis</u> especially in <u>small veins</u>. b) <u>Peri-vascular injection</u> (extravasation) → <u>Tissue necrosis</u> e.g. <u>SC tissues</u> <u>Median nerve damage</u> in <u>antecubital fossa</u> so, if this occurs, the <u>needle</u> should be <u>left in place</u> and <u>hyaluronidase</u> should be <u>injected</u>. c) <u>Intra-arterial injections</u> Due to <u>inadvertent injection</u> especially in <u>brachial artery</u> or an <u>aberrant ulnar artery</u> in <u>antecubital fossa</u>. C/O • <u>Intense burning pain</u>. • <u>Forearm</u> and <u>hand</u> may become <u>blanched</u> and <u>blisters</u> may appear <u>distally</u>. <u>Mechanism</u>: <u>ischemia</u> and <u>gangrene distally</u> due to • <u>VC</u> • <u>Local release of noradrenaline</u>. • <u>Formation of emboli</u> due to - <u>Formation of thiopental crystals</u> in the <u>arterioles</u>. - <u>Endarteritis</u> → <u>thrombosis</u>. - <u>Platelet aggregation</u> due to <u>ATP released</u> from <u>damaged cells</u>. <u>Treatment</u>: • <u>Stop injection</u> immediately with <u>any intense pain</u>. • <u>Leave the needle</u> in the <u>artery</u> and inject <u>vasodilator</u> in it as <u>papaverine</u> 20 mg. • <u>Stellate ganglion block</u> or <u>brachial plexus block</u>. • <u>I.v. heparin</u> and <u>postoperative oral anticoagulant</u>. ⑤ <u>Allergic reactions</u>: It ranges from <u>skin rash</u> up to <u>severe anaphylactic</u> or <u>anaphylactoid</u> reactions. 	<p>① <u>CNS</u>:</p> <ul style="list-style-type: none"> - <u>Drowsiness</u> persists for hrs. - <u>Excitatory phenomenon</u> on <u>induction</u> (++) It is <u>dose related</u>. It includes • <u>Dyskinetic movement</u> which ↓ by <u>premedication</u> with <u>opioid</u>. • <u>Coughing</u> and <u>hiccups</u> which ↓ by <u>premedication</u> with <u>anticholinergics</u> - <u>Emergence phenomenon</u> is <u>absent</u> (-) - <u>Epileptic form</u> activity in EEG in <u>epileptic patient</u>. ② <u>Respiratory depression</u>. ③ <u>CVS depression</u>. ④ <u>During injection</u> a) <u>I.v. injections</u> (1% solution) <u>more pain</u> and <u>thrombophlebitis</u> especially in <u>small veins</u>. b) <u>Peri-venous injections</u>: <u>more rare</u> than <u>thiopentone</u> c) <u>Intra-arterial injections</u> <u>more rare</u> than <u>thiopentone</u> ⑤ <u>Allergic reaction</u> <u>rare</u>
Indication	<p>① <u>Induction of anesthesia</u>.</p> <p>② <u>Maintenance of anesthesia</u>: It is only suitable for <u>short procedures</u> as <u>cumulation</u> occurs with <u>repeated doses</u>.</p> <p>③ <u>Basal narcosis</u> by <u>rectal route</u>.</p> <p>④ <u>Treatment of status epilepticus</u>.</p> <p>⑤ <u>↓ ICP</u>.</p>	<p>① <u>Induction of anesthesia</u> when <u>rapid recovery</u> is needed as in</p> <ul style="list-style-type: none"> - <u>Output anesthesia</u>. - <u>Electroconvulsive therapy</u>. <p>② <u>Maintenance of anesthesia</u>: It is only suitable for <u>short procedures</u></p> <p>③ <u>Basal narcosis</u> by <u>rectal route</u></p> <p>As thiopentone</p>
Contra-indication ① Absolute	<p>① <u>Airway obstruction</u>.</p> <p>All <u>i.v. anesthetics</u> should not be given if there is <u>anticipated difficulty</u> in maintaining an <u>adequate airway</u>.</p> <p>② Previous <u>hypersensitivity</u> reactions.</p> <p>③ <u>Porphyria</u> as it → induction of <u>amino-levulinic acid synthetase</u> → stimulates formation of <u>porphyrins</u> (an intermediary in <u>heme synthesis</u>) → precipitate <u>acute attack</u> of <u>lower motor neuron paralysis</u> or <u>C.V.S collapse</u>.</p>	

Propofol	Etomidate	Ketamine HCl
<p>① <u>CNS:</u></p> <ul style="list-style-type: none"> - <u>Excitatory phenomenon</u> (+) - <u>Emergence phenomenon</u> (-) - <u>Convulsions</u> occur with epileptic patients. <p>② <u>Respiratory depression</u></p> <p>③ <u>C.V.S. depression (more than other agents).</u></p> <p>④ <u>During injection</u></p> <p>Ⓐ I.v. injections <u>More pain</u> especially in small veins. The incidence ↓ if 10 mg lignocaine is given shortly before it or if 10 mg lignocaine is mixed with it in the <u>syringe</u>. No <u>thrombophlebitis</u></p> <p>Ⓑ <u>Peri-venous injections</u> no effect</p> <p>Ⓒ <u>Intra-arterial injections</u> no effect</p> <p>⑤ <u>Allergic reaction</u> Less than <u>thiopentone</u></p> <p>⑥ <u>Long term sedation of children in ICU</u> is associated with <u>lipemia</u>, <u>metabolic acidosis</u> and <u>death</u>.</p>	<p>① <u>CNS:</u></p> <ul style="list-style-type: none"> - <u>Excitatory phenomenon</u> (+++) (the worst) - <u>Emergence phenomenon</u> (+) - <u>Postoperative nausea & vomiting</u> (+) 30% <p>② <u>Respiratory depression</u></p> <p>③ <u>C.V.S. depression less than other agents.</u></p> <p>④ <u>During injection</u></p> <p>Ⓐ I.v. injections <u>The worst Pain</u> and <u>Thrombophlebitis</u> especially in <u>small veins</u>. It ↓ by....</p> <p>Ⓑ <u>Peri-venous injections</u> no effect</p> <p>Ⓒ <u>Intra-arterial injections</u> no effect</p> <p>⑤ <u>Allergic reaction</u> very rare</p> <p>⑥ <u>Adreno-cortical suppression</u></p>	<p>① <u>CNS:</u></p> <ul style="list-style-type: none"> - <u>Excitatory phenomenon</u> (+) - <u>Emergence phenomenon</u> (++) <p><u>Restlessness</u>, <u>delirium</u>, <u>disorientation</u>, <u>agitation</u>, <u>vivid and unpleasant nightmares</u> or <u>hallucination</u> during <u>recovery</u> and up to 24 hrs. Its incidence ↓ by <u>avoidance of verbal and tactile stimulation</u> during <u>recovery period</u> or by <u>concomitant use of opioid</u>, <u>butyrophenones</u>, <u>benzodiazepines</u> or <u>physostigmine</u>. It is <u>less in children and elderly</u>.</p> <ul style="list-style-type: none"> - <u>↑ ICP & prolonged recovery</u> - <u>Postoperative nausea & vomiting</u> (++) <p>② <u>Respiratory system:</u> No</p> <p>③ <u>C.V.S.</u> <u>Harmful in hypertensive and ischemic heart patients.</u></p> <p>④ <u>During injection:</u> No effect</p> <p>⑤ <u>Allergic reaction:</u> <u>skin rash</u> may occur.</p> <p>⑥ <u>Salivation.</u></p>
<p>① <u>Induction of anesthesia</u> especially for <u>outpatient anesthesia</u>.</p> <p>② <u>Sedation during regional anesthesia, ICU, and endoscopy.</u></p> <p>③ <u>TIVA:</u> the <u>most suitable agent</u>.</p>	<p>① <u>Induction of anesthesia</u> especially for</p> <ul style="list-style-type: none"> - <u>Outpatient anesthesia</u>, but it is replaced now by <u>propofol</u> - Patients with <u>compromised C.V.S.</u> 	<p>① <u>Induction of anesthesia</u> especially for</p> <ul style="list-style-type: none"> - <u>High risk patient (shocked patient)</u> - <u>Pediatric anesthesia in minor surgery</u>, <u>investigations</u> (e.g. <u>cardiac catheterization</u>), <u>ophthalmic examination</u> or <u>radiotherapy</u>. - <u>Difficult location</u> e.g. <u>site of accident</u> and in <u>causalities of wars</u>. - <u>Developing countries</u> when <u>anesthetic equipment</u> and <u>trained staff</u> are in <u>short supply</u>. <p>② <u>Analgesia</u> e.g. in <u>wound dressing</u>, or <u>positioning of patients with pain</u> before <u>regional anesthesia</u> (e.g. <u>fracture neck femur</u>).</p>
<p>① <u>Airway obstruction.</u></p> <p>② <u>Previous hypersensitivity.</u></p> <p>③ <u>Long term sedation in children in ICU</u> due to a number of <u>adverse outcomes</u> It is <u>safe in Porphyria</u>.</p>	<p>① <u>Airway obstruction.</u></p> <p>② <u>Previous hypersensitivity.</u> ③ <u>Long term infusion.</u></p> <p>④ <u>Porphyria.</u></p> <p>⑤ <u>Adrenal insufficiency.</u></p>	<p>① <u>Airway obstruction.</u></p> <p>② <u>Porphyria (doubt).</u></p> <p>③ <u>↑ ICP.</u></p>

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	Thiopentone sodium	Methohexitone sodium
(b) Relative Contra-indication & Precautions	<p>① CNS: Outpatient anesthesia due to <u>slow recovery</u> and <u>drowsiness</u>.</p> <p>② Respiratory: <u>Bronchial asthma</u> <u>Muscle disease</u>: e.g. <u>Myasthenia gravis</u> or <u>dystrophia myotonica</u> → <u>exaggerated respiratory depression</u>.</p> <p>③ CVS: It is used <u>cautiously</u> (<u>small dose</u> and <u>slow i.v. injections</u>) In <u>hypovolemia</u> ---- see before.</p> <p>④ Renal disease as <u>chronic renal failure</u>. There is <u>↓ protein binding</u>. <u>Excretion is not effected</u> so, <u>normal dose</u> can be used but <u>very slowly</u>.</p> <p>⑤ Severe hepatic disease: There is <u>decreased protein binding</u> and <u>impaired metabolism</u>, but this has a <u>little effect on recovery</u> so, <u>normal dose</u> can be used but <u>very slowly</u>.</p> <p>⑥ Obstetrics: <u>Adequate dose</u> must be given to the <u>mother</u>, but <u>excessive dose</u> may → <u>respiratory & C.V. depression</u> in <u>fetus</u> especially if <u>induction-delivery interval</u> is <u>short</u>.</p> <p>⑦ Patients with ↓ metabolic rates (<u>myxedema</u>, <u>extremes of age</u>, <u>adreno-cortical insufficiency</u>) <u>care</u> should be taken during usage.</p>	<p>as thiopentone except</p> <p>① It is <u>suitable</u> for <u>outpatient anesthesia</u>.</p> <p>② It should <u>not be used</u> in <u>epileptic patients</u>.</p>
Drug interaction	<p>① <u>Contrast media</u>, <u>sulfonamide</u>, <u>phenylbutazone</u> and other drugs <u>displace thiopentone</u> from <u>plasma protein binding sites</u> → <u>↑ free drug</u> → <u>↑ systemic side effects</u>.</p> <p>② <u>Ethanol</u>, <u>narcotics</u>, <u>antihistamines</u> and other <u>CNS depressants</u> → <u>potentiate the sedative effect</u> of <u>barbiturates</u>.</p> <p>③ <u>β adrenergic blockers</u> → <u>potentiate C.V.S. depression</u>.</p> <p>④ It is an <u>enzyme inducer</u>.</p>	

Propofol	Etomidate	Ketamine HCl
<p>As <u>thiopentone</u> except</p> <p>① <u>More suitable</u> (than barbiturates) for <u>outpatient anesthesia</u>.</p> <p>② <u>Less suitable</u> (than barbiturates) for patients with <u>C.V.S. diseases</u>.</p> <p>N.B.; <u>History of egg allergy</u> does <u>not</u> necessarily <u>contraindicate</u> the use of propofol because <u>most egg allergies</u> involve reaction to <u>egg white</u> (egg albumin), while <u>egg lecithin</u> is extracted from <u>egg yolk</u>.</p> <p>① with <u>previous formulation</u> containing <u>Cremophor El</u>, it potentiates <u>non-depolarizing muscle relaxants</u> (not with <u>newer formulation</u>)</p> <p>② <u>Fentanyl & alfentanil concentrations</u> may be <u>↑</u> by <u>concomitant administration</u> of propofol.</p>	<p>As <u>thiopentone</u> except.</p> <p>① <u>More suitable</u> for <u>outpatient anesthesia</u>.</p> <p>① <u>Opioid</u> (as <u>premedication</u>) → <u>↓ excitatory phenomenon</u>, but <u>delays recovery</u> so, becomes <u>not suitable</u> for <u>outpatient anesthesia</u>.</p> <p>② <u>Fentanyl & alfentanil concentrations</u> may be <u>↑</u> by <u>concomitant administration</u> of <u>etomidate</u>.</p>	<p>① <u>Not suitable for outpatient anesthesia</u> due to</p> <ul style="list-style-type: none"> - <u>Prolonged recovery</u>. - <u>Emergence phenomenon</u>. <p>② <u>Not suitable</u> for patients with</p> <ul style="list-style-type: none"> - <u>Coronary artery disease</u>. - <u>Hypertensive patients</u>. - <u>Congestive heart failure</u>. - <u>Aortic aneurysm</u>. <p>③ <u>Not suitable for frequent procedures</u> e.g. frequent <u>radiotherapy</u> due to its <u>prolonged recovery</u> → <u>disturbs sleep & eating pattern</u> on repeated administration.</p> <p>④ It <u>poorly suppresses the response to visceral stimulation</u> so, <u>opioid supplementation</u> is given when <u>visceral stimulation is anticipated</u>.</p> <p>① <u>Non-depolarizing muscle relaxant</u> → <u>potentiation</u>.</p> <p>② <u>Theophylline</u> may → <u>seizures</u></p> <p>③ <u>Diazepam</u> → <u>attenuates ketamine's cardio-stimulatory effects</u> and <u>↑ its elimination t_{1/2}</u></p> <p>④ <u>Sympathetic antagonists</u> as <u>propranolol</u> and <u>phenoxylbenzamine</u> → <u>unmask the direct myocardial depressant effect of ketamine</u>.</p> <p>⑤ <u>Lithium</u> → <u>prolongs duration</u> of ketamine.</p> <p>⑥ <u>Halothane, benzodiazepines or barbiturates</u> → <u>↓ distribution and clearance</u> → <u>prolonged action</u>.</p> <p>⑦ <u>Halothane and other volatile agents</u> → <u>potentiate myocardial depression</u>.</p>

Q: What are the properties of ideal i.v. anesthetics ?

Total Intravenous Anesthesia (TIVA)

Definition:

TIVA: The use of i.v. anesthetic agents **alone** to produce general anesthesia.

IVA: the use of i.v. anesthetic agents + N₂O to produce general anesthesia.

Indications and Advantages:

1. It allows **rapid recovery** of consciousness and psychomotor function by propofol as compared with other agents (although new volatile agents as desflurane and sevoflurane → rapid recovery also).
2. It allows **high inspired O₂ concentration** in situations where hypoxemia may occur as one-lung anesthesia, severely ill, or traumatized patients and in severe lung diseases (to avoid lung as a route of uptake of inhalational agents).
3. **To avoid using N₂O** e.g. in middle ear surgery, bowel surgery, ↑ ICP.
4. **To avoid affection of hypoxic pulmonary V.C. reflex** which is adversely affected by volatile agents compared with i.v. agents.
5. TIVA is safe in **malignant hyperthermia** (compared with volatile agents).

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6. It allows **access** as during laryngoscopy or bronchoscopy when delivery of inhalational agents is difficult.
7. **Less incidence of nausea & vomiting** (compared with volatile agents).
8. **To maintain somato-sensory evoked potential** e.g. CNS surgery (compared with volatile agents).
9. **To control intraocular pressure** in ophthalmic surgery (compared with volatile agents).
10. To maintain **anesthesia for ARDs patients ventilated with ICU ventilators.**

Disadvantages:

1. It needs a **separate i.v infusion site** (cannula).
2. It needs an **infusion device** e.g. infusion pump or syringe pump.
3. It is unsuitable for patients with **upper airway obstruction** because induction must be by inhalational routes.
4. Possibility of **awareness** is high due to the high degree of patient variability in response to drugs.
5. **Opioids can cause respiratory depression, and muscle rigidity** interfering with ventilation.

Components:

1. Hypnotics → unconsciousness and amnesia.
E.g. propofol, ketamine, methohexitone, etomidate, and midazolam.
2. Analgesics → to inhibit reflex response to surgery.
E.g. opioids (fentanyl, alfentanil, sufentanil).
3. Muscle relaxants → to provide muscle relaxation.
E.g.....
4. O₂ enriched air.

(Mention every drug in more details)

Monitoring During TIVA For Depth of Anesthesia: (see CNS Monitoring)

- 1- Clinical signs as a noxious stimulus;
 - somatic responses as pain and movement.
 - autonomic responses as change in HR, BP, breathing.
- 2- Spontaneous EMG activity.
- 3- EEG.
- 4- Esophageal contractility (has limitations).
- 5- Mid-latency auditory evoked potential.
- 6- Bi-spectral monitor.

Techniques:**1. Intermittent Injections:**

- It is acceptable only for procedures of short duration in unparalyzed patients because the plasma concentration of the drug & the anesthetic effect vary widely.

2. Manual infusion techniques:

- The infusion rate required to achieve a predetermined target plasma concentration of an i.v. drug can be calculated by;

$$\text{Infusion rate } (\mu\text{g/min}) = \text{Steady state plasma concentration } (\mu\text{g/mL}) \times \text{clearance (mL/min)},$$
 but actually clearance is variable from one patient to another so, it is difficult to calculate infusion rate (figure 3-9).

a. A constant infusion:

- It is not good because the serum concentration of the drug increases slowly taking 4-5 times the elimination $t_{1/2}$ of the drug to reach steady state.

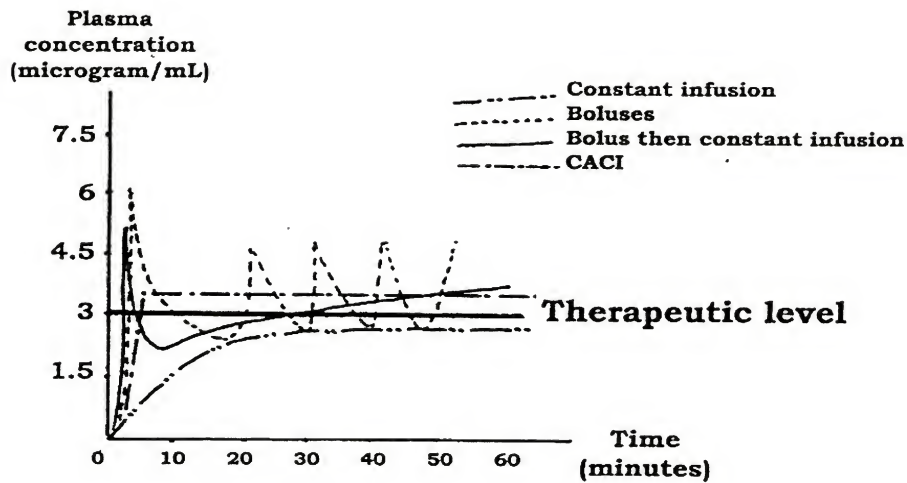


Figure 3-9; Plasma concentration with different methods of administration

b. A bolus injection followed by constant infusion:

It causes excessive concentration (with ↑ incidence of side effects) initially i.e. the target concentration is initially exceeded, which is followed by a prolonged dip below the target concentration.

c. Multi-step infusion regimen

It is commonly used with propofol as:

Bolus dose	1 mg/kg.
then	10 mg /kg /hr for the 1 st 10 min
then	8 mg/kg /hr for the 2 nd 10 min
then	6 mg/kg /hr for the remaining time.

This allows, on average, the target plasma concentration to be reached, allowing satisfactory anesthesia in unparalyzed patients who receive N₂O & fentanyl. Higher infusion rates are needed if N₂O & fentanyl are not used.

3. Computer-Driven Techniques (Target Controlled Infusion System, TCI System) (Computer-Assisted Continuous Infusion, CACI):

By programming a computer with appropriate pharmacokinetic data and equations, it is possible at frequent intervals (several times a minute) to calculate the appropriate infusion rate required to produce a preset target plasma concentration of the drug.

The drug is infused by a syringe driver which is under control of a computer, so, at first, the syringe driver infuses the drug very rapidly (as a slow bolus) and then delivers the drug at a progressively decreasing infusion rate.

To decrease plasma concentration, the syringe driver stops the infusion until the computer calculates that the target concentration is reached and then infuses the drug at an appropriate rate to maintain a constant level.

The anesthetist is required only to enter the desired target concentration and to change it when clinically indicated (figure 3-10).

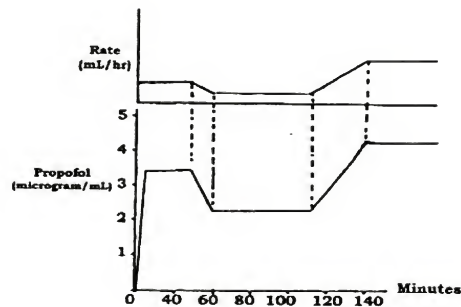


Figure 3-10; TCI System or CACI

PHARMACOLOGY OF ANESTHESIA**Advantages:**

- 1- Simple
- 2- The rapidity with which plasma concentration can be changed (especially upwards)
- 3- Avoidance of the need for the anesthesiologist to undertake any calculations (avoid errors).

Disadvantages: **Inaccurate**, as the actual concentration achieved may be > 50% greater then or less than the predicted concentration. This is not a major practical disadvantage assuming that the anesthesiologists adjust the target concentration according to clinical signs related to the adequacy of anesthesia.

By using this technique in female patients;

The minimum target concentration of propofol required to prevent movement in response to a surgical incision in 50% of subjects (the equivalent of MAC) is

6 µg/mL when patients breathe O₂.

4.5 µg/mL when patients breathe O₂: N₂O (33%: 67%).

SKELETAL MUSCLE RELAXANTS

Nicotinic Receptor:

It consists of 5 subunits; 2 α, 2 β, and one ε (epsilon) in an adult, or γ (gamma) in a fetus (figure 3-11).

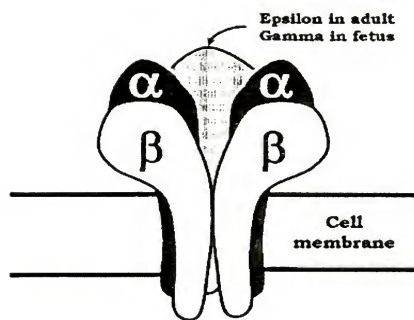

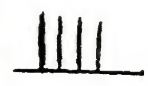
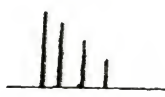
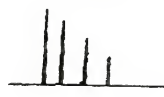
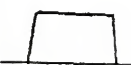
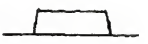


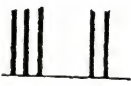
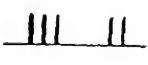
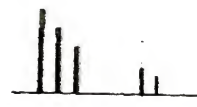
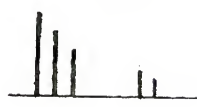






Figure 3-11; Nicotinic receptor

Distinction between

	Depolarizing (Non-Competitive) Blockade	Non-Depolarizing (Competitive) Blockade
Mechanism of action Ach= Acetylcholine	① Phase I block (depolarizing): - They resemble Ach so, they bind to Ach receptors → muscle action potential i.e. Ach receptor agonist. - Unlike Ach, they are <u>not metabolized</u> by true <u>acetylcholine esterase</u> . So, they <u>react repeatedly</u> with <u>receptors</u> as one will be attached to the receptor after the other is separated → <u>prolonged depolarization of muscle end-plates</u> → <u>opening of Na channels</u> which then <u>closes</u> (time limited) → once the channel closes → <u>disappearance of muscle action potential</u> → muscle	- They bind to <u>one or two of α subunits</u> in <u>Ach nicotinic receptors</u> (they have at least one <u>quaternary ammonium group</u> N ⁺ (CH ₃) ₃ bind to α subunits), but they are <u>incapable</u> of inducing the <u>conformational change</u> necessary for <u>ion channel opening</u> i.e. the channel <u>remains closed</u> . Ach is <u>prevented</u> from <u>binding</u> to its receptor → <u>no end-plate potentials</u> i.e. <u>competitive inhibition</u> . There is <u>no fasciculation</u> .

	<p>relaxation. These Na channels can <u>not reopen</u> until the <u>end-plate repolarizes</u> which is <u>not possible</u> as long as the <u>depolarizing muscle relaxant</u> continues to <u>bind</u> to Ach receptors.</p> <p>- There is <u>fasciculation</u> followed by <u>relaxation</u>.</p> <p>② <u>Phase II block (desensitization, 2ry non depolarizing, dual block)</u>:</p> <p>- It occurs on <u>repeated</u> or <u>prolonged</u> administration of <u>suxamethonium</u> which produces a <u>block resembling</u> a <u>non-depolarizing block</u></p> <p>- This is <u>due to receptor desensitization</u> i.e. <u>ionic and conformational changes</u> that occur in the receptors due to <u>prolonged muscle membrane depolarization</u>.</p> <p>- It is treated by <u>anticholinesterase</u> e.g. <u>neostigmine</u>.</p>	<p>N.B.; This explains;</p> <ul style="list-style-type: none"> • Conditions with a <u>chronic ↓ in Ach release</u> (e.g. <u>muscle denervation injuries</u>) stimulate a <u>compensatory ↑ in number of Ach receptors</u> i.e. <u>Up regulation</u> → <u>exaggerated response</u> to <u>depolarizing muscle relaxants</u> (with <u>more receptors being depolarized</u>), but a <u>resistance to non-depolarizing muscle relaxants</u> (<u>more receptors that must be blocked</u>). • Conditions with <u>↓ Ach receptors</u> (e.g. <u>myasthenia gravis</u>) i.e. <u>Down Regulation</u> → <u>resistance to depolarizing muscle relaxants</u> & <u>↑ sensitivity to non-depolarizing muscle relaxants</u>.
Reversal of block	<p>- <u>No specific agent</u> to reverse <u>depolarizing blockade</u>, but the <u>depolarizing muscle relaxants</u> (which are not metabolized by true acetylcholine esterase) <u>diffuse away from the neuromuscular junction (NMJ)</u> & are <u>hydrolyzed in the plasma and liver by pseudo cholinesterase (Non-specific, plasma, or pseudo)</u></p> <p>- <u>Anticholinesterases</u> (e.g. <u>neostigmine</u>) →</p> <ul style="list-style-type: none"> • They <u>inhibit acetylcholine esterase</u> → <u>↑ Ach at NMJ</u> → <u>intensify the block</u>. • They <u>inhibit pseudo-cholinesterase</u> → <u>↓ hydrolysis of suxamethonium</u>. <p>→ <u>Potentiate N.M. blockade</u>.</p>	<p>- With the <u>exception of mivacurium</u>, <u>non-depolarizing muscle relaxants</u> are <u>not significantly metabolized</u> by either <u>acetylcholine esterase</u> or <u>pseudo-cholinesterase</u>. <u>reversal of their blockade</u> depends on <u>redistribution, gradual metabolism & excretion</u>.</p> <p>- <u>Anticholinesterases</u> (e.g. <u>neostigmine</u>) → They <u>inhibit acetylcholine esterase</u> → <u>↑ Ach</u> amount available at <u>NMJ</u> to <u>compete</u> with the <u>non-depolarizing muscle relaxants</u>. → <u>reversal of the block</u>.</p>

Response to peripheral nerve stimulator	Phase I	Phase II	Non-depolarizing block
1- Train-of-four 	Constant but ↓ 	Fade 	Fade 
2- Tetany 	Constant but ↓ 	Fade 	Fade 
3- Double burst stimulation DBS 	Constant but ↓ 	Fade 	Fade 
4- Post-tetanic potentiation 	Absent 	Present 	Present 

Suxamethonium ^{chloride} (Succinylcholine or Diacetylcholine)

Chemical structure:

It is a **quaternaly ammonium** compound (amine).

It consists of two joined acetylcholine molecules linked together (figure 3-12).

The two radicals N^+ $(CH_3)_3$ have the capacity to bind to each of the α subunits of postsynaptic Ach receptors.

Dose:

1.0 – 1.5 mg/Kg i.v.

Onset:

60 sec (to reach 95% block).

It is the most rapid of all muscle relaxants.

(N.B.; onset of rocuronium almost equals that of succinylcholine)

Duration:

Recovery starts within 3 min and

is complete within 12-15 min (25% recovery at 10 min).

Indications:

Tracheal intubation in

- 1- Patient with full stomach or obstetric surgery.
- 2- If difficult tracheal intubation is expected (to reach the optimum conditions for intubation).

Pharmacokinetics:

• Metabolism:

- In plasma by pseudo-cholinesterase (98-99%) at a very rapid rate → succinyl-monocholine.
- In plasma by other nonspecific esterases.
- In the liver (very little).

• Excretion:

- By the kidneys as • Water soluble inactive metabolites (mainly).
• Unchanged in urine (10%).

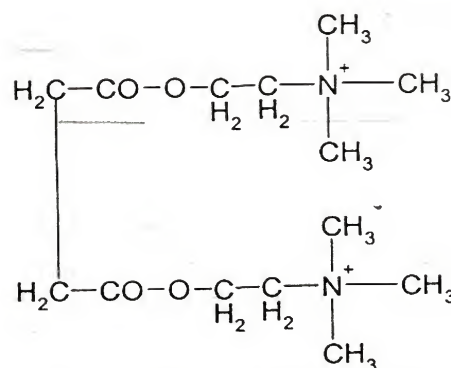
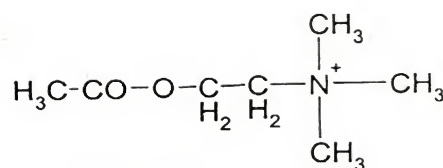


Figure 3-12; Acetylcholine (above)
and suxamethonium (below)

Causes of Prolongation of Duration of Action (Succinylcholine

Apnea): i.e. abnormal metabolism.

① Inherited Factors:

- Plasma cholinesterase structure is determined genetically by autosomal genes (E_1^u) Gene abnormalities cause abnormal structure.

① Atypical gene (E_1^a) (in 4% of Caucasians).

* Heterozygote (E_1^u, E_1^a): → prolonged action of suxamethonium about 20-30 min.

* Homozygote (E_1^a, E_1^a): → prolonged action of suxamethonium e.g. 6-8 hrs.

② Fluoride gene (E_1^f): rare.

③ Silent gene (E_1^s):

* Homozygote (E_1^s, E_1^s) → prolonged action of suxamethonium > 3 hrs up to 24 hrs.

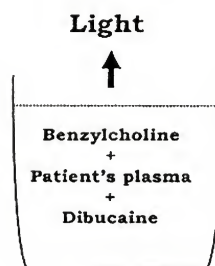
It has very little capacity to metabolize suxamethonium so, the later is actually metabolized by nonspecific esterases in plasma.

Treatment:

- ① Keep the patient anesthetized (to avoid risk of awareness) & the lungs are ventilated artificially.
- ② Monitor NM transmission accurately until full recovery from residual NM block occurs.
- ③ Fresh frozen plasma containing cholinesterase.
- ④ Studying the details of the genetic status of the patient and the immediate relatives. A warning card or alarm bracelet is given to them.
- ⑤ A plasma sample is taken to measure the patient's cholinesterase activity, it should be taken several days after the prolonged block has been discovered as suxamethonium decreases plasma cholinesterases.

Detecting abnormal cholinesterase structure is done by the following;

- If the plasma of a normal genotype patient is added to a water bath containing a substrate as benzylcholine, a chemical reaction occurs with plasma cholinesterase as benzylcholine reacts with the normal enzyme. This reaction will emit light of a given wavelength which can be detected by spectrophotometer.



- Addition of dibucaine (local anesthetic) to the water bath, inhibits pseudo-cholinesterase and inhibits this reaction, therefore, no light is produced.

Figure 3-13; Detection of abnormal cholinesterase structure

Dibucaine inhibits normal pseudo-cholinesterase activity by 80 %.

But it inhibits the heterozygous enzyme by 40- 60 %

and inhibits the homozygous enzyme by 20 %

The percentage of inhibition of pseudo-cholinesterase activity is called dibucaine number which is proportional to the pseudo-cholinesterase function and independent of the amount of enzyme.

- Addition of fluoride to the water bath (instead of dibucaine) → inhibition of reaction → detection of fluoride gene.
- Without addition of anything and no reaction occurs → detection of silent gene.

⑩ Acquired Factors:

The activity of plasma cholinesterase is decreased (although the structure is normal) causing prolonged action of suxamethonium for a few minutes.

Cause:

- 1- ↓ enzyme synthesis as: liver disease, starvation, carcinomatosis, and pregnancy.
- 2- ↓ enzyme activity as in: hypothyroidism, and hypothermia.
- 3- ↑ enzyme removal as in: plasmapheresis, cardiopulmonary bypass.
- 4- Renal disease.
- 5- Anti-cholinesterases inhibit both Ach esterase & pseudo-cholinesterase.
- 6- Other drugs that are metabolized by plasma cholinesterase decrease its availability as:
 - Etomidate • Pancuronium • Ester local anesthetics • Mivacurium
 - MAOIs • Anticancer drugs as methotrexate and cyclo-phosphamides.

Side effects:

- ① Succinylcholine Apnea: see before.
- ② Muscle pain: postoperatively.
 - Most probably due to initial fasciculations.

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- Common in: patients who are ambulant soon after surgery as day-case patients.
patients who have a large muscle mass as young fit patients.
Female patients.

- Rare in: extremes of age.
pregnancy (as usually the fasciculations are little)

- Site of pain:

In unusual sites as diaphragm and between the scapulae.

- Treatment: pain is not relieved by conventional analgesics.

Pre-curarization (pretreatment):

A small dose (10-15%) of non-depolarizing muscle relaxant is given immediately (5 min) before suxamethonium e.g. gallamine 10 mg (which is the most efficacious) or atracurium 2.5 mg. This will decrease the potency of suxamethonium so, larger doses of suxamethonium 1.5 mg/kg should be used to get the same effect (as already some receptors will be occupied by the small amount of non-depolarizing muscle relaxant).

③ Cardiovascular effects:

- Suxamethonium and its metabolite succinyl monocholine, affect muscarinic receptors in SA node leading to direct vagal effect. This causes sinus bradycardia & ventricular ectopy.

- It is common in:

- Patients with high vagal tone as children and physically fit individuals.
- Repeated doses of suxamethonium.

So, it is advisable to give anticholinergics routinely on repeated suxamethonium doses especially in children.

④ Hyperkalemia:

- Normally, muscles release during suxamethonium administration about 0.5 mmol/L K⁺ may be due to muscle fasciculation. This is insignificant in normal persons with normal K⁺ levels.

- It is not affected (i.e. no benefit) by pre-curarization.

- Conditions which cause hyperkalemia include;

- ① Dennervation injuries in muscles cause proliferation of extra-junctional receptors (up regulation). e.g. * Burn injury * Poly-neuropathies
* Spinal cord injury * Paraplegia
* Myopathies as muscular dystrophies, dystrophia myotonica.

② Massive tissue trauma

- e.g. - Poly-trauma.
- Severe intra-abdominal infections.
- Closed head injury, encephalitis and stroke.

All cause tissue destruction which results in increased s. K⁺.

The risk of hyperkalemia usually appears from the 4th day up to the 10th week after injury (with peak 7-10 days), but the exact time of onset and duration of the risk is variable.

Suxamethonium is considered contraindicated in the routine management of children and adolescents due to the risk of rhabdomyolysis, hyperkalemia, and cardiac arrest in those with undiagnosed myopathies.

- ③ Renal failure, as already s. K⁺ is high.

⑤ Malignant Hyperthermia:

- Suxamethonium is a potent triggering agent. It increases the chance from 1: 250 000 with other anesthetic drugs to up to 1: 60 000 with suxamethonium (i.e. nearly 5-folds).

Suxamethonium may cause contraction of the masseter muscles resulting in difficult intubation.

⑥ Increased Intra-gastric Pressure:

- In the presence of a normal lower esophageal sphincter, the increased intragastric pressure by abdominal muscle fasciculation is not sufficient to produce regurgitation because the increased intragastric pressure is offset by an increase in the lower esophageal sphincter tone.
- In patients with incompetent esophageal sphincter e.g. hiatus hernia, regurgitation may occur.
- Pre-curarization abolishes the rise of both gastric pressure and lower esophageal sphincter tone.

⑦ Increased Intraocular Pressure:

- It is due to fasciculation of external ocular muscle
- It is not abolished by pre-curarization.
- It lasts for as long as the neuro-muscular block.
- It may cause expulsion in open eye injury.

⑧ Increased Intracranial Pressure:

- Suxamethonium slightly increases CBF causing increased ICP. This can be abolished by pre-curarization.
- Also, muscle fasciculations stimulate muscle stretch receptors which subsequently increase cerebral activity.

⑨ Anaphylactic reactions:

- It is rare. On repeated exposure, it causes histamine release.

Non-Depolarizing Muscle Relaxants

Include;

① Benzyl Iso-quinolinium Compounds:

They tend to release histamine

- | | |
|-------------------------|-------------------------|
| ① <u>d-tubocurarine</u> | ② <u>Metocurine</u> |
| ③ <u>Alcuronium</u> | ④ <u>Gallamine</u> |
| ⑤ <u>Atracurium</u> | ⑥ <u>Cis-atracurium</u> |
| ⑦ <u>Mivacurium</u> | ⑧ <u>Doxacurium</u> |

② Amino-steroid compounds: They tend to be vagolytic

- | | |
|-----------------------|-----------------------|
| ① <u>Pancuronium</u> | ② <u>Pipecuronium</u> |
| ③ <u>Vecuronium</u> | ④ <u>Rocuronium</u> |
| ⑤ <u>Rapacuronium</u> | |

N.B.; Due to structural similarities, an allergic history to one muscle relaxant highly suggests the possibility of allergic reactions to other muscle relaxants.

N.B.;

- The drug is usually administrated incrementally every 1/2 the duration after the intubating dose e.g. if the clinical duration after the intubating dose is 30 min, the drug is given in incremental dose every 15 min.
- The less potent drugs require a higher dose. This will increase the drug delivery to the N.M. junction which causes shorter duration of action.

Q: What are the non-relaxant effects of muscle relaxants?

A: Discuss the side effects of depolarizing & non-depolarizing muscle relaxants.

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	d-Tubocurarine	Metocurine	Alcuronium	Gallamine (Flexidil)	Atracurium Besylate	Cis-Atracurium (Nimbex)
Chemical structure There must be at least one quaternary amine that binds to α subunit of nicotinic receptors	Mono-quaternary amine. It is the only natural muscle relaxant.	Bis-quaternary amine It is a derivative of tubocurarine (di-methyl tubocurarine)		Tri-quaternary amine	Mono-quaternary amine It must be stored at 2-8 °C in a refrigerator as it loses 5-10% of its potency each month if exposed to room temperature.	It is R-Cis -R' Cis isomer of atracurium It is the most recent It must be stored as atracurium.
Onset To reach 95% block	Moderate (2-3 min)	Moderate (2-3 min)	Moderate (2-3 min)	Moderate (2-3 min)	Moderate (2-3 min)	Moderate (2-3 min)
Duration (After the intubating dose)	Long acting (100-120 min)	Long acting (100-120 min)		Long acting (100-120 min)	Intermediate acting (20-30 min)	Intermediate acting (45-60 min)
Dose - Loading = 1/2 of intubating dose - Incremental = 1/4 of loading dose or 1/10 of the intubating dose.	- Intubating 0.5-0.6 mg/kg - Loading 0.15 mg/kg - Increments 0.05 mg/kg every 30 min	- Intubating dose 0.3 mg/kg - Loading 0.08 mg/kg - Increments 0.03 mg/kg every 30 min	- Intubating 0.2 mg/kg	- Intubating 160 mg in adult	- Intubating 0.5 mg/kg - Loading 0.25 mg/kg - Increments 0.1 mg/kg every 20 min - Infusion 5-10 µg/kg/min.	- Intubating 0.1 mg/kg (4 times more potent than atracurium) - Infusion 1.0 - 2.0 µg/kg/min.
Metabolism & Excretion	• Kidney: (mainly) 60-80% • Bile: 10% • Liver: insignificant	• Kidney: (mainly) 98% • Bile: < 5% • Liver: insignificant	• Kidney: (almost entirely) 100%	• Kidney: (almost entirely) 100%	• Hoffmann degradation 45% i.e. spontaneous non-enzymatic breakdown at physiologic temperature & pH so, it is safe in patients with renal or liver dysfunction → laudanosine which is epileptogenic (not in humans?) even with large doses. • Ester hydrolysis in plasma by nonspecific esterases 40% • Kidney or bile excretion: 10%	• Hoffmann degradation mainly as it is more potent than atracurium so, less dose is given so, less laudanosine than equipotent dose of atracurium No effect by non-specific esterases.
Side Effects To decrease them, slow administration of muscle relaxant (over 1-3 min) is essential	① Histamine release: (++) → ↓ ABP → reflex ↑ HR bronchospasm skin flare ② CVS: ganglion blockade in large doses → It potentiates the previous C.V.S. effects.	① Histamine release: (+) less (1/2 of tubocurarine) → Less C.V.S. Less bronchospasm Less skin flare ② CVS: ganglion blockade less (than tubocurarine)	① Histamine releases: (+) → Less C.V.S. Less bronchospasm Less skin flare ② CVS: some vagolytic effect → mild ↑ HR.	① Histamine release: No ② CVS: Potent vagolytic effect Some direct sympathomimetic (+) → ↑ ABP & ↑ HR ③ Cross placenta so, not used in obstetrics (as it is more lipid soluble than others).	① Histamine release: (+) less (1/3 of tubocurarine) → less CVS & --- ② CVS: slight ↓ or no direct effect. ③ Laudanosine Toxicity: It stimulates CNS → ↑ MAC and may cause fits (not in human). It occurs with high doses or with hepatic failure (as it is metabolized in the liver). ④ Hypothermia or acidosis → ↓ Hoffmann degradation → ↑ duration ⑤ Precipitates as free acid if mixed in venous line containing alkaline solution as thiopentone.	① Histamine release: No ② CVS: No direct Effect so, CVS is stable ③, ④ & ⑤ As Atracurium

FLASHLIGHTS ON ANESTHESIA

Mivacurium	Doxacurium	Pancuronium (Pavulon)	Pipecuronium (Arduan)	Vecuronium (Norcuron)	Rocuronium (Esmeron)	Rapacurium
<u>Bis-quaternary amine</u>	<u>Bis-quaternary amine</u>	<u>Bis-quaternary amine</u> It must be stored at 2-8 °C	<u>Bis-quaternary amine</u> It is a <u>pancuronium analogue</u>	<u>Mono-quaternary amine</u> It is a <u>pancuronium analogue</u>	<u>Mono-quaternary amine</u> It is a <u>vecuronium analogue</u>	It is a <u>vecuronium analogue</u>
Moderate (2-3 min)	Slow (4-6 min)	Moderate (2-3 min)	Moderate (2-3 min)	Moderate (2-3 min)	Rapid 60-90 sec, so, suitable for rapid sequence induction.	Rapid within 60 sec. It has the most rapid onset
Short acting (10-20 min) - <u>Intubating</u> 0.15 mg/kg - <u>Infusion</u> 5-10 µg/kg/min.	Long acting (120-150 min) - <u>Intubating</u> 0.05 mg/kg (the most potent) - <u>Loading</u> 0.02 mg/kg - <u>Increments</u> 0.005 mg/kg every 20-40 min	Long acting (60-90 min) - <u>Intubating</u> 0.08-0.1 mg/kg - <u>Loading</u> 0.04 mg/kg - <u>Increments</u> 0.01 mg/kg every 30-45 min	Long acting (60-90 min) - <u>Intubating</u> 0.08-0.1 mg/kg	Intermediate (45-60 min) - <u>Intubating</u> 0.08-0.1 mg/kg - <u>Loading</u> 0.04 mg/kg - <u>Increments</u> 0.01 mg/kg every 15-20 min - <u>Infusion</u> 1-2 µg/kg/min	Intermediate (45-60 min) - <u>Intubating</u> 0.5-0.9 mg/kg - <u>Infusion</u> 5-10 µg/kg/min (as <u>atracurium</u>) - <u>I.m.</u> 1-2 mg/kg within 3-6 min onset.	Short acting (10-20 min) - <u>Intubating</u> 1.5 mg/kg - <u>I.m.</u> 3-5 mg/kg within 3 min onset.
• <u>Plasma cholinesterase</u> (95-99%). It may not need anti-cholinesterase for reverse (if N.M function is monitored). If plasma cholinesterase abnormality is inherited or acquired → ↑ action duration e.g. renal or hepatic failure (although not eliminated by them) In contrast to <u>suxamethonium</u> its block is reversed by anti-cholinesterase • <u>Kidney</u> : < 5% • <u>True cholinesterase</u> : Minimal %.	• <u>Kidney</u> : (mainly) > 90% • <u>Plasma cholinesterase</u> : 6%	• <u>Kidney</u> : 60-85% • <u>Liver</u> : 30% → some active metabolites which are excreted by the kidney. • <u>Bile</u> excretion: 10%	• <u>Kidney</u> : 60-90% • <u>Liver</u> : 20% • <u>Bile</u> : 20%	• <u>Kidney</u> : 25-40% • <u>Liver</u> : 5% • <u>Bile</u> : (mainly) 70% N.B.; The dose should be decreased in biliary obstruction and in liver diseases (as it is associated with biliary stasis)	• <u>Kidney</u> : 40% • <u>Liver</u> : insignificant • <u>Bile</u> : (mainly) 60%	• <u>Kidney</u> : mainly • <u>Liver</u> : insignificant, but into an active metabolite called 3- des-acetyl metabolite
① & ② as <u>atracurium</u>	①&② as <u>cis-atracurium</u>	①&② as <u>gallamine</u> ③ It inhibits plasma choline esterase → potentiates drugs metabolized by this enzyme e.g. <u>suxamethonium</u> <u>mivacurium</u>	①&② as <u>cis-atracurium</u>	①&② as <u>atracurium</u> ③ It precipitates with thiopental → thrombo-embolism of i.v. line → pulmonary embolism	① & ② as <u>alcuronium</u>	① as <u>atracurium</u> , but it causes severe broncho-spasm, so it is withdrawn from the market

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Q : Give accounts on a muscle relaxant e.g. Rocuronium?

A: Discuss

1. Chemical structure
2. Mechanism of action
3. Onset and duration
4. Dose
5. Metabolism and excretion
6. Indications
7. Side effects
8. Reverse
9. Monitoring & type of block
10. Drug interactions.
11. Factors affecting onset and duration.

Q: What are the different doses of the muscle relaxant?

- A: 1. Intubating dose.
 2. Loading (initial) dose.
 3. Maintenance (incremental) dose.
 4. Infusion dose.
 5. Pre-curarization doses.
 6. Priming dose.
 7. Intramuscular dose.

Factors affecting the onset of non-depolarizing muscle relaxants:

To speed the onset of non-depolarizing muscle relaxants;

① **Increase the dose:** of the non-depolarizing muscle relaxant, but this also increases the side effects.

② **Priming dose:**

- Method: Give 10-15% of the usual intubating dose 5 minutes before induction.

- Value: It speeds the onset for intubation

E.g.: 60 sec for rocuronium

90 sec for other intermediate-acting relaxants.

- Mechanism: This small priming dose will occupy enough receptors so that, paralysis will quickly follow when the balance of the relaxant is given.

It does not usually cause clinically significant paralysis because that requires 75-80% of receptors to be blocked (a N.M. margin of safety).

- Side effects: In some patients, the priming dose occupies enough receptors to produce - Dyspnea or dysphagia.

- Muscle weakness.

- Significant reduction in the respiratory function (e.g. forced vital capacity) may produce hypoxia.

So, Induction of anesthesia should proceed without delay.

Q: What are the factors affecting the muscle relaxants action?

A: Discuss factors affecting suxamethonium duration.

& the factors affecting the onset and the duration of the non-depolarizing muscle relaxants.

Factors Affecting Duration of Non-Depolarizing Muscle Relaxants:

① Body Temperature:

- Hypothermia potentiates blockade by either;
 Decreasing the metabolism e.g. atracurium, and mivacurium.
 Or decreasing the excretion e.g. tubocurarine, metocurine, and pancuronium.
 E.g.: during cardiopulmonary bypass So, decrease the dose of relaxants.

② pH Changes:

- Metabolic (and to a lesser extent respiratory) acidosis potentiates blockade with mono-quaternary amines.

③ Electrolyte Changes:

- Hypokalemia → potentiates blockade
- Hypocalcemia → potentiates blockade by decreasing presynaptic Ach release.
- Hypercalcemia → Unpredictable response.
- Hypermagnesemia → potentiates blockade by competing with Ca^{++} at the motor end-plate.

④ Age:

- Neonates show increased block due to increased sensitivity of the immature N.M.J. to non-depolarizing muscle relaxants, but, this does not necessarily decrease the dosage because the neonate's greater E.C. space provides a larger volume of distribution which may cause resistance to the usual dosage.
- Children of school age show some resistance to the usual doses.
- Old age patients show an increased block due to deterioration of organs which decrease metabolism and excretion.

⑤ Concurrent diseases:

- Hepatic failure and chronic renal failure change pharmacokinetics of drugs as they increase the volume of distribution that, in turn, decreases plasma concentration for a given dose of water soluble agents as muscle relaxants, but drugs dependent on hepatic or renal excretion show prolonged elimination.

So, the net effect is usually;

A greater loading (initial) dose and a smaller incremental (maintenance) dose.

- In myasthenia gravis, there is a decrease in the number and half life of postsynaptic receptors by auto-antibodies produced in the thymus gland so, patients are more sensitive to the effect of non-depolarizing muscle relaxants (but resistance to suxamethonium may occur).

⑥ Muscle Groups:

The onset and intensity of blockade varies among muscle groups. This is due to the differences in • Their blood flow.

- Their distance from the central circulation.
- Agent used.

In general, the diaphragm, laryngeal muscles and orbicularis oculi respond to and recover from muscle relaxation earlier than the thumb.

⑦ Drug interaction.

Drug Interactions of Muscle Relaxants:

① Non-Depolarizing Muscle Relaxants + Suxamethonium:

- Non-depolarizing muscle relaxants antagonize suxamethonium in phase I block, (as non-depolarizing muscle relaxants occupy some Ach receptors so, depolarization by suxamethonium is partially prevented as occurring in pre-curarization). An exception to this interaction is pancuronium as it augments suxamethonium blockade by inhibiting pseudo-cholinesterase.
- Non-depolarizing muscle relaxants potentiate suxamethonium in phase II block.

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- Similarly, an intubating dose of suxamethonium potentiates the blockade of non-depolarizing muscle relaxants.

② Others:

Ⓐ Drugs potentiating both depolarizing and non-depolarizing muscle relaxants:

- Antibiotics (streptomycin, polymyxin, tetracycline, gentamycin, and clindamycin).
- Anti-arrhythmics (Quinidine, lidocaine, Ca⁺⁺ channel blockers, and procainamide).
- Antihypertensive (trimethaphan, and nitroglycerin affect pancuronium only).
- Inhalational agents; isoflurane and enflurane > halothane > N₂O.
- Local anesthetics.
- Mg sulfate.

Ⓑ Drugs potentiating non-depolarizing muscle relaxants only.

- Ketamine.
- Dantrolene.

Ⓒ Drugs potentiating depolarizing and inhibiting non-depolarizing muscle relaxants: • Anti-cholinesterases (e.g. neostigmine), see above for the mechanisms.

Reverse of Muscle Relaxants:

By anticholinesterase;

- It is safest to have some degree of spontaneous recovery before anticholinesterases are given, because their effectiveness depends on the degree of recovery present when they are given.
- More intense blocks require a longer recovery time, and neostigmine is more effective than edrophonium in antagonizing intense blockade.
- Increasing the dose of reversal can help shorten the recovery time, but there is no benefit in administering neostigmine at more than 70 µg/kg.
- Short-acting N.M. blockers are reversed faster than intermediate ones, which recover faster than long-acting relaxants.
- Anticholinergics as atropine (0.02 mg/kg) or glycopyrrolate should be added to the reversal to block the muscarinic side effects of anticholinesterases.

Local Anesthetics (LAs)

Theories of LA Actions:

Na⁺ channels are inactivated by LAs preventing subsequent channel activation (opening) therefore, no Na⁺ influx occurs. This leads to a slow rate of depolarization which does not reach the threshold level therefore, no action potential occurs. This occurs by one of the following;

LA are Na⁺ channel blockers: most LAs bind to Na⁺ channels (simply plug them)

- On preparation, LAs are usually prepared in an acid solution as HCl salt (pH 6-7), LAs containing epinephrine are prepared in more acidic solutions (pH 4-5) as epinephrine is unstable in alkaline media so, tertiary amine group becomes quaternary and then they become water soluble and suitable for injection.

- After injection, the pH increases due to buffering in the tissues therefore, a proportion of the drug, determined by pKa, dissociates to release a free base which is lipid soluble so, it can pass via the lipid cell membrane to the interior of the axon. (pKa = is the pH at which the amounts of ionized and non-ionized drug is equal).

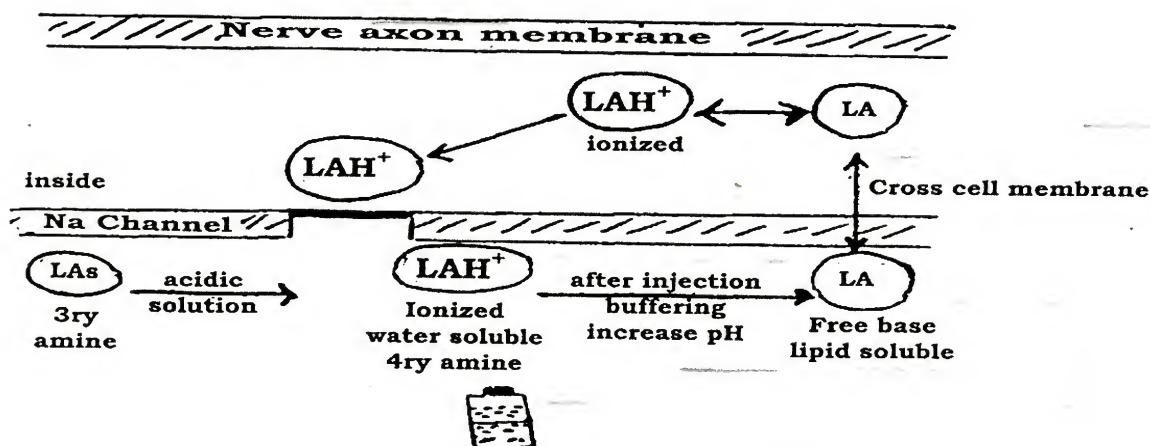


Figure 3-14; Mechanism of action of LAs

- Inside the axon, re-ionization occurs and the re-ionized forms enter Na^+ channels and block them.
- Actually, because re-ionization occurs intracellularly so, individual drug pKa has a little effect on the rate of onset of blockade.
- The drug also enters capillaries and is removed by the circulation, eventually, tissue concentration decreases below that in the nerves. The drug diffuses out and restoration of normal function occurs.

N.B.; The amine group is either tertiary or quaternary.

The tertiary amine is more lipid soluble therefore, the compound can cross cell membranes, BBB, GIT, and placenta. It can be taken by any route. E.g. atropine, physostigmine, and LAs.

The quaternary amine is more water soluble therefore, the compound cannot cross the physiologic membranes. It is taken mainly by i.v. route. E.g. glycopyrrolate, neostigmine, edrophonium, pyridostigmine, and muscle relaxants.

Structure-Activity Relationship

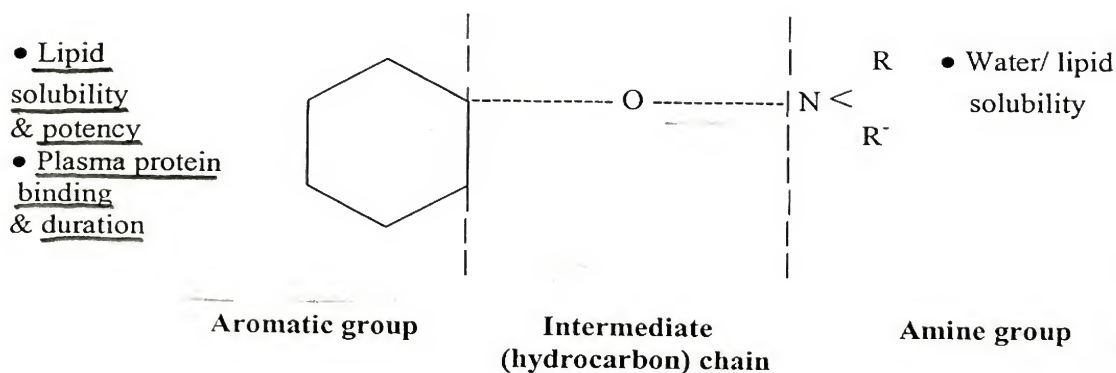


Figure 3-15; Structure of local anesthetics

LAs consist of;

① Aromatic Group (Benzene Ring):

- It determines:
- Fat solubility and so the potency (lipophilic group)
 - Duration of plasma protein binding, as Na^+ channel is protein in nature

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so, drugs that bind to proteins for a longer time, have a longer duration of action.

② **Tertiary Amine Group:**

It determines its water solubility (hydrophilic group) at physiologic pH, tertiary amines usually carry positive charges so, they are weak bases.

③ **Intermediate Chain:**

It is the basis for LA classification.

It is either; - Amino-amine LAs (with amide linkage).

- Amino-ester LAs (with ester linkage). (Figure 3-16)

It determines the differences between the esters and amide LAs (see later).

Potency

- It depends on;

① Lipid solubility: as increased lipid solubility is associated with increased potency.

② Molecular weight: as increased M.W. by an increased number of carbon atoms in the molecule is associated with increased potency.

e.g. adding a butyl group to mepivacaine (less potent) → bupivacaine (more potent).

- Relative potency is measured by:

④ **Minimum Local Anesthetic Concentration (Cm or MLAC):**

It is the minimum concentration of local anesthetic that will block nerve impulse conduction (it is analogous to MAC of inhalational anesthetics).

Or it is the median effective local anesthetic concentration in a 20 mL volume for epidural analgesia in the first stage of labor.

⑤ **Minimum Effective Anesthetic Concentration (MEAC):**

It is the concentration at which a spinal anesthetic agent produces surgical anesthesia within 20 minutes of administration in 50 % of patients.

Speed of Onset of Action:

It depends on;

① **pKa of the drug:**

- LAs with pKa closer to the physiologic pH i.e. decreased pKa will have a higher concentration of non-ionized free base that can pass through the nerve cell membrane producing more rapid onset.

- E.g. Lidocaine has a more rapid onset of action (its pKa is 7.8) than other LAs with pKa 8.5.

② **MW of LAs:**

- LAs with low MW have more rapid onset of action so,

① pH of commercially prepared drugs: as it is usually acidic so, if injected in infected (acidic) tissues, a delayed onset is produced.

② If carbonated solutions of LAs rather than HCl salts are used, rapid onset occurs due to improved intracellular distribution of the ionized form.

③ Alkalinization of LAs by adding NaHCO₃ (e.g. 1 mL 8.4% NaHCO₃ per 10 mL 1% lidocaine) produces a more rapid onset and improves the quality of the block due to the increased amount of free base available.

Duration of Action

It depends on; the aromatic group which determines the lipid solubility which in turn, determines the duration of plasma protein binding:

As increased lipid solubility is associated with increased plasma protein binding in blood, this decreases the clearance of LAs. Also, Na⁺ channels are protein in nature so, drugs bind to proteins (and Na⁺ channels) for a longer time and have a longer duration of action.

Tachyphylaxis

It is the decrease of efficacy of repeated doses due to the eventual consumption of local extracellular buffering capacity by the acidic LAs.

Pharmacokinetics

(Factors increasing systemic toxicity* can be detected from it)

Absorption:

Factors affecting systemic absorption:

① Site of injection:

- Increased vascularity* at the site of injection results in increased systemic absorption and so, increases systemic toxicity.

- I.v. > tracheal > intercostal > caudal > paracervical > epidural > brachial plexus > sciatic > subcutaneous > skin.

② Presence of vasoconstrictors*:

- VC decreases systemic absorption therefore;

• It decreases systemic toxicity so, the dose can be increased safely by 50-100%.

• It increases duration and intensity of block.

- The effect of VC is more pronounced with short acting drugs e.g. addition of epinephrine to lidocaine, but epinephrine with long acting drugs e.g. bupivacaine does not produce significant effects as the long duration of bupivacaine is due to its high degree of protein binding.

③ Types of LAs:

- LAs which are highly tissue bound, are more slowly absorbed e.g. etidocaine.

- LAs vary with their intrinsic vasodilator properties except cocaine which has VC action.

Distribution:

- LAs are protein bound in blood; - Primarily to α_1 - acid glycoprotein.
and - Secondarily to albumin.

Metabolism and Excretion

	<u>Esters</u>	<u>Amides</u>
<u>Metabolism</u>	<p>- <u>Rapidly</u> by <u>pseudo-cholinesterase</u>. So, patients with <u>genetically abnormal pseudo-cholinesterase</u>* are at <u>increased risk of toxicity</u> due to the <u>slower rate of metabolism</u>.</p> <p>- <u>N.B.</u>; <u>Cocaine</u> is <u>partially metabolized</u> by the <u>liver</u> and <u>partially excreted unchanged</u> by the <u>kidneys</u></p>	<p>- <u>Slowly</u> by <u>microsomal enzymes (amidases)</u> in the <u>liver</u>. So, - <u>↓ hepatic function</u> (cirrhosis) - <u>↓ blood flow</u> (congestive heart failure) Both* → <u>↓ metabolism</u> → <u>↑ toxicity</u>. <u>N.B.</u> <u>Prilocaine</u> is <u>metabolized</u> to a <u>greater degree</u> by the <u>lungs</u>, but <u>more rapidly</u> by the <u>liver</u>.</p>
<u>Hyper-sensitivity</u>	- <u>More common</u> due to one of its <u>metabolites, P-amino-benzoic acid (PABA)</u> which is <u>highly allergic</u> .	- <u>Less common</u>
<u>Stability</u>	- <u>Heat sensitive</u> & tend to <u>hydrolyze spontaneously</u> on <u>warming</u> so, they have <u>short shelf lives</u> .	- <u>Heat insensitive</u> so, they have <u>long shelf lives</u> (unless <u>mixed with glucose</u> to produce <u>hyperbaric spinal solutions</u>).

N.B.; - Termination of action of intrathecally injected LAs depends upon their absorption into the blood stream where esters are hydrolyzed by pseudo-cholinesterase and amides are metabolized in the liver.

- Plasma protein binding does not affect acute toxicity of drugs.

PHARMACOLOGY OF ANESTHESIA

- Amides in glucose and esters are heat sensitive, but can be heat sterilized once and should be used soon after autoclaving.

Q: Compare between esters & amides?

4: Discuss the cause of classification, differences and examples.

Clinical Factors Affecting Drug Profile:

- ① Increased dose of the drug* causes more rapid onset and prolonged duration.
Increased dose occurs either by increasing the concentration or increasing the volume. A larger volume of a dilute solution is usually more effective.
- ② Site of injection*: see before
- ③ Pregnancy, short stature and elderly* have increased segmental spread of extradural.
- ④ Young, fit, obese, alcoholic or anxious patients* require more drugs.
- ⑤ Additives: see later.

Local Anesthetic Drugs

A) Esters:

- ① Cocaine: It has high toxicity and produces VC.
- ② Benzocaine: It has high protein binding so, it has long duration.
- ③ Procaine: It has high lipid solubility so, it has high potency.
- ④ Chloro-procaine: It has low toxicity so, its maximum dose is 12 mg/kg because it is highly cleared by plasma esterases.
- ⑤ Amethocaine(tetracaine)

B) Amides:

- ① Lignocaine or Lidocaine (Xylocaine):
 - It has medium lipid solubility so, it is with medium potency. Its pKa is 7.8.
 - It has medium protein binding so, it is with medium duration.
 - It has medium toxicity.
 - Its maximum safety dose is 4.5 mg/kg without adrenaline.
7.0 mg/kg with adrenaline.
 - It is used also as an antiarrhythmic drug.
- ② Mepivacaine or Carbocaine:
 - As lignocaine
- ③ Bupivacaine (Marcaine):
 - It is R-bupivacaine.
 - It has high lipid solubility so, it is with high potency. Its pKa is 8.1.
 - It has high protein binding so, it is with long duration.
 - It has more toxicity than lignocaine especially CVS and CNS toxicity.
 - Its maximum safety dose is 3 mg/kg.

N.B.; Levo-bupivacaine (S-bupivacaine) is a new local anesthetic. It is less cardiotoxic than R-isomer bupivacaine.

④ Ropivacaine (Naropin):

- As bupivacaine (chemically derived from bupivacaine)....., but;
- Less cardiotoxic and less CNS toxicity (due to less lipid solubility)
- More vasoconstrictor action so; more prolonged duration. Its pKa is 8.1.
- It produces greater separation of sensory and motor blockade so, it is the drug of choice for epidural use in obstetric and postoperative analgesia.
- Its ampoule is 10 mL 7.5 mg/mL (0.75%). At this concentration, it acts motor and sensory. When 26.5 mL normal saline are added to the ampoule, 2 mg/mL (0.2%) is obtained which acts mainly on sensory fibers.

⑤ **Dibucaine:**

- It is highly toxic.
- It is used for detection of abnormal pseudo-cholinesterase.

⑥ **Etidocaine:**

- It is highly toxic.
- On contrast to other local anesthetics, it has more profound effect on motor than sensory fibers.

⑦ **Prilocaine:**

- It has very low toxicity so, its maximum safety dose is 8 mg/kg.
- It is the best agent for intravenous regional anesthesia.

Q: Discuss ropivacaine?

A: The following points should be discussed;

- Mechanism of action.
- Chemical structure.
- Pharmacokinetic.
- Toxicity and side effects.
- Dose.
- Uses.
- Drug interactions.

Systemic Effects and Systemic Toxicity

N.B.; Systemic effects includes specific and toxic effects.

Systemic toxicity includes toxic effects (due to drug over-dosage) only.

Causes: ① The most common cause is inadvertent intravascular injections.

②. Absolute over-dosage.

Factors Affecting Systemic Toxicity = Factors Affecting Pharmacokinetics
See above

N.B.; - Toxicity is often directly proportionate to potency.

- Mixtures of LAs should be considered to have roughly additive toxic effects
e.g. a solution containing 50% of the toxic dose of lidocaine and 50% of the toxic dose of bupivacaine will have 100% of the toxic effects of either drug.

① **CNS Effects:**a) **Toxicity:**

- The earliest features are numbness and tingling of the tongue and circumoral area because of their very rich blood supply depositing enough drug affecting the nerve endings at these sites.
- Then CNS stimulation as tinnitus, blurred vision, restlessness, agitation, nervousness, and muscle twitches up to convulsions occurs. They are due to selective blockade of inhibitory pathways.
- Finally, CNS depression as slurred speech, drowsiness, unconsciousness up to respiratory arrest occurs.

b) **Specific Effects:**

- ① Lidocaine (i.v. 1.5 mg/kg) decreases CBF, ICP during intubation.
- ② Lidocaine 5%, tetracaine 0.5%, or chloro-procaine (formulated with Na meta-bisulfite) on repeated doses via continuous spinal analgesia causes cauda equina syndrome, transient neurologic symptoms, and persisting sacral root irritation due to pooling of the drug around the cauda equina in high concentration leading to permanent neuronal damage.
- ③ Cocaine stimulates CNS and usually causes a sense of euphoria.

PHARMACOLOGY OF ANESTHESIA**② CVS Effects:****a) Toxicity: -ve effects**

1. ↓ myocardial automaticity.
2. ↓ duration of refractory period.
3. ↓ myocardial contractility.
4. ↓ conduction velocity.
5. VD (except cocaine causes VC).

-
- ↓ HR up to heart block.
 - ↓ ABP up to circulatory collapse

Due to blocking of cardiac Na⁺ channels.

b) Special Effects:

- Lidocaine in low dose, has an antiarrhythmic effect and decreases the pressor response to intubation.

③ Respiratory Effects:**a) Toxicity: respiratory depression up to arrest in large doses.****b) Specific:**

- ① Lidocaine depresses hypoxic drive (i.e. respiratory response to low PaO₂).
- ② Direct exposure to LAs causes depression of medullary respiratory center e.g. post-retrobulbar apnea syndrome.

Other Additional Side Effects:**① Allergic Reactions:**

- It is more with esters ⊗ amides especially procaine due to para-amino benzoic acid (a known allergen) produced on hydrolysis.

② Musculoskeletal Effects:

- Direct injection into skeletal muscles causes myofibril hyper-contraction which progresses to lytic degeneration, edema and necrosis. Regeneration usually occurs after 3-4 weeks.

③ Met-hemoglobinemia:

- Especially with prilocaine and benzocaine.

- Fetal Hb in the neonates is more sensitive so, it is better to avoid prilocaine in epidural anesthesia during labor.

Prevention of Systemic Toxicity:**① The single most important factor is avoidance of accidental intravascular injection by:**

- ① Careful aspiration tests should be repeated each time the needle is moved.
- ② Initial injection of 2-3 mL of solution containing adrenaline 1:200 000. If there is an increase in the HR within 1-2 min, this indicates intravascular injection.
- ③ Repeated aspiration tests after each 5-10 mL of solution.
- ④ Inject slowly.
- ⑤ Careful patient observation for early signs of toxicity is important so, injection can be stopped before occurrence of major toxicity.

② Avoidance of over-dosage by

- Consideration of the behavior of various drugs after injection at a particular site.
- Use the appropriate drug and dose for each block.
- Maximum safe dosage should be considered (with or without adrenaline).
- Patient's general condition.
- Concomitant use of general anesthesia.

Treatment of Toxicity:

Mainly supportive treatment

1. Facilities for treatment must always be available before doing the block.
2. Respiration: maintain airway, supply O₂ by face mask up to artificial ventilation.
3. Convulsions: small increments of diazepam 2.5 mg.
4. C.V.S. collapse: adrenergic drugs with α and β agonists e.g. ephedrine 5 mg increments.

Additives:**a) For Pharmaceutical Purposes:**

- ① Na hydroxide and HCL acid To adjust pH.
- ② Na chloride To adjust tonicity.
- ③ Glucose and water To adjust baricity.

N.B.; Heavy Marcaine is bupivacaine (Marcaine) with 8% glucose.

- ④ Preservatives e.g. methyl hydroxyl benzoate so, it is not used for subarachnoid or epidural block.
- ⑤ NaHCO₃ To speed the onset.

b) For Pharmacologic Purposes:**1) Vasoconstrictors:**

Aim: VC decreases rate of absorption —→

- Decreased systemic toxicity.
- Increased duration and intensity of block especially for short acting drugs e.g. lidocaine.

Agents: Adrenaline: → the most potent and the most commonly used.

Noradrenaline, phenylephrine, and felypressin are less commonly used.

Dose: Adrenaline concentration : should not exceed 1:200 000

Maximal dose: should not exceed 0.5 mg.

N.B.: 1: 200 000

i.e. 1 gm: 200 000 mL

i.e. 1000 mg in 200 000 mL

i.e. 1 mg in 200 mL

Contraindications:

- ① Injection close to end arteries e.g. ring block of digits and penis.
- ② I.v. regional anesthesia.
- ③ Theoretically, increase the risk of permanent neurologic deficit by rendering nerve tissues ischemic.
- ④ Cardiac patients: due to systemic effects of vasoconstrictors.
- ⑤ Interaction with other sympathomimetic drugs including tricyclic antidepressants and adrenergic drugs.
- 2) CO₂: Many LAs are commercially produced as the carbonated salt with CO₂ dissolved under pressure in the solution. Therefore, after injection, CO₂ decreases intracellular pH that increases the ionized active form of the drug speeding up the onset of the block.
- 3) Dextrans: Mixing LAs with high molecular weight dextrans (especially with adrenaline) produces macromolecules which hold LAs in tissues for longer periods. This increases the duration of action.
- 4) Hyaluronidase: To break down tissues barriers therefore, aiding the spread of LAs e.g. ophthalmic local anesthesia.

5) Mixtures of LAs: E.g.: lidocaine + bupivacaine**Advantages:**

- To achieve the rapid onset of lidocaine and the long duration of bupivacaine.
- To decrease toxicity, but actually LA toxicity is additive so that, the use of 50% of doses of both LAs can cause 100% of the toxic effects of either drug.
- E.g.: Amide + ester.

Toxicity increases as amide inhibits pseudo-cholinesterase and so, decreases hydrolysis of ester LAs.

6) Other analgesic drugs: → ↑ duration and intensity of the block of LAs

- E.g.: - Opioid (morphine, pethidine or fentanyl).
- Ketorolac.

PHARMACOLOGY OF ANESTHESIA

- Clonidine (75-150 mg for epidural).
- Ketamine (0.4 mg for each mL of epidural solution) (0.5 mg/kg).
- Neostigmine.

EMLA cream

- It is Eutectic (easily melted) Mixture of Local Anesthetics (EMLA).
- It consists of 1:1 mixture of unionized forms of 5% lidocaine and 5% prilocaine (by other authors, 2.5% lidocaine and 2.5% prilocaine) in oil in water emulsion.
- **Onset:** 1 hour.
- **Duration:** 1-2 hour.
- **Pharmacological actions and uses:**
It produces dermal analgesia sufficient for; 1- I.v. line insertion especially in pediatric.
2- Split-thickness skin graft harvesting.
3- Laser removal of port-wine stains.
4- Lithotripsy.
5- Circumcision.
- **Side effects:** Skin blanching, erythema, and edema.
- **Contraindications:**
 1. On mucous membranes or broken skin as great absorption occurs causing met-hemoglobinemia.
 2. Infants less than one month old.
 3. Patients with predisposition to met-hemoglobinemia (due to prilocaine).
- **Dose:** • Given 1 hour, before the procedure.
• 1-2 gm of cream applied per 10 cm² area of skin.

OPIOID (OPIATE, NARCOTIC)

ANALGESICS

Classification

A) **Pure Opioid Agonist:** i.e. they produce dose-dependant agonist activity

① **Natural Opium Alkaloids:**

- Phenanthrenes: - Morphine - Codeine (methyl morphine) - Papavertum
- Benzylisoquinolines: - Noscapine - Papaverine

② **Semi-Synthetic Opium Alkaloids:** - Dia-morphine (heroin)

- ③ **Synthetic Opioids:** - Pethidine - Fentanyl - Alfentanil
 - Sufentanil - Remifentanil - Tramadol
 - Methadone

B) **Partial Opioid Agonist:**

At low doses, they antagonize pure opioid induced analgesia.

At high doses, they produce analgesia with ceiling (plateau) effect whatever the dose is.

- Buprenorphine

C) **Opioid Agonist/Antagonist:**

They have an agonist effect on one receptor type and an antagonist effect on another receptor type.

- Pentazocine - Butorphenol - Levallorphan
- Nalorphine - Nalbuphine (Nubain)

D) **Pure Opioid Antagonists:**

- Naloxone (Narcan) - Naltrexone - Methyl naltrexone
- Nalmiphen - Alvimopan

Mechanism of Action:

a) In The Brain:

- Opioids excite neurons in peri-aqueductal grey matter (PAG) and in the nucleus reticularis paragiganto-cellularis (NRPG) causing stimulation of nucleus raphe magnus (NRM).
- From the latter 5-HT and enkephalin containing neurons run to substantia gelatinosa of the dorsal horn that lead to an inhibitory effect on transmission.

B) In The Spinal Sites:

- Opioids also act directly on the dorsal horn. Locus caeruleus (LC) sends norepinephrine neurons which inhibit the dorsal horn (figure 3-16).

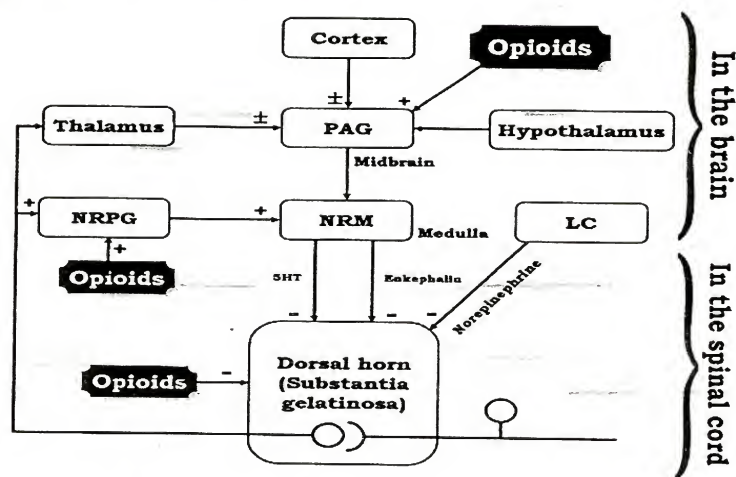


Figure 3-16; Mechanism of action of opioids

Opioid receptors:

Receptor	Clinical Effects	Agonist	Antagonist	Molecular Mechanism
Mu (μ)	<ul style="list-style-type: none"> • $\mu 1$: high affinity 1. <u>Central analgesia</u> 2. <u>Spinal analgesia</u> 3. <u>Euphoria</u> 4. <u>Miosis</u> 5. <u>Dependence</u> 6. <u>Muscle rigidity</u> • $\mu 2$: low affinity 7. <u>Respiratory depression</u> 8. <u>Gut inhibition</u> 	<ul style="list-style-type: none"> - <u>Morphine</u> - <u>Pethidine</u> - <u>Fentanyl</u> - <u>Sufentanil</u> - <u>Buprenorphine</u> (partial agonist) - <u>met-enkephalin</u> - <u>β-endorphin</u> 	<ul style="list-style-type: none"> - <u>Pentazocine</u> - <u>Nalbuphine</u> - <u>Naloxone</u> - <u>Naltrexone</u> 	<ul style="list-style-type: none"> - It acts via <u>Gi protein</u> → • <u>(-) adenylyl cyclase</u> • <u>(+) K^+ channel opening</u> → <u>$\uparrow K^+$ efflux</u> → <u>hyper-polarization</u>
Kappa (κ)	<ul style="list-style-type: none"> 1. <u>Spinal analgesia</u> 2. <u>Sedation and dysphoria</u> 3. <u>Miosis</u> 4. <u>Respiratory depression</u> 	<ul style="list-style-type: none"> - <u>Morphine</u> - <u>Pentazocine</u> - <u>Nalbuphine</u> 	<ul style="list-style-type: none"> - <u>Naloxone</u> 	<ul style="list-style-type: none"> - It inhibits <u>voltage dependent N-type Ca^{++} channels</u> on <u>pre-synaptic terminals</u> → <u>\downarrow release of neurotransmitters</u> as <u>substance P</u> and <u>glutamate</u>
Delta (δ)	<ul style="list-style-type: none"> 1. <u>Central analgesia</u> (in <u>high doses only</u>) 2. <u>Spinal analgesia</u> 3. <u>Dependence</u> 4. <u>Gut endotoxigenic shock</u> 	<ul style="list-style-type: none"> - <u>Morphine</u> - <u>met-enkephalin</u> - <u>leu-enkephalin</u> - <u>β-endorphin</u> 	<ul style="list-style-type: none"> - <u>Naloxone</u> 	<ul style="list-style-type: none"> As <u>Mu receptors</u> (<u>Gi</u>)
Sigma (σ) (Nociceptin)	<ul style="list-style-type: none"> 1. <u>Vasomotor center stimulation</u> 2. <u>Dysphoria</u> and <u>hallucination</u> 3. <u>Mydriasis</u> 4. <u>Respiratory stimulation</u> 	<ul style="list-style-type: none"> - <u>Pentazocine</u> - <u>Nalbuphine</u> - <u>Nalorphine</u> - <u>Ketamine</u> 	<ul style="list-style-type: none"> - It is <u>not a true opioid receptor</u> as it is <u>not reversed by naloxone</u> 	<ul style="list-style-type: none"> It acts via <u>glutamate activated ion channels</u>

PHARMACOLOGY OF ANESTHESIA

	Morphine	Pethidine (Meperidine)
Chemical structure	- Natural opium alkaloid, pure agonist, tertiary amine, weak base. Although it is possible to synthesize, it is produced commercially from the dried juice of the seed capsules of Poppy Papaver Somniferum.	- Synthetic pure agonist
Pharmacokinetics	<p>- <u>Lipid solubility</u>: (+) → <u>slow onset</u> <u>Peak effect</u>: <u>15-20 min</u> after i.v. & <u>60-90 min</u> after i.m. - <u>Duration</u>: <u>3-4hrs</u> after i.v. or i.m. (it is usually <u>↑</u> more due to <u>active metabolites</u>) - <u>Protein binding</u>: (++) 35% - <u>Metabolism</u>: • Mainly in the <u>liver</u> by <u>dealkylation</u>, <u>oxidation</u> and <u>conjugation</u> with <u>glucuronides</u> → <u>morphine-3-glucuronide</u> and <u>morphine-6-glucuronide</u>, the later is <u>active</u> (more potent and longer duration) than <u>morphine</u> so, <u>clinical effect</u> may <u>exceed</u> that expected from $t_{1/2\beta}$ especially in renal impairment. • There is <u>high 1st pass effect</u> (70%) in the <u>gut wall</u> and <u>liver</u> → <u>low bioavailability</u> after <u>oral route</u> (30%) so, <u>relatively higher doses</u> are needed. At the same time <u>morphine-6-glucuronide</u> is also <u>higher</u> than with i.v and i.m route so, <u>oral morphine dose</u> is <u>effective</u>. - <u>Excretion</u>: • As <u>water soluble end products</u> by the <u>kidney</u> • <u>5-10%</u> are excreted <u>unchanged</u> by the <u>kidney</u> So, in <u>renal impairment</u>, there is <u>↑ duration of action</u> • <u>10%</u> are excreted <u>unchanged</u> by the <u>bile</u>, <u>stool</u>, <u>saliva</u>, <u>sweat</u> and <u>milk</u>.</p>	<p>- <u>Lipid solubility</u>: (++) → <u>more rapid onset</u> than morphine - <u>Duration</u>: <u>2-3hrs</u> <u>Protein binding</u>: (+++) - <u>Metabolism</u>: • In the <u>liver</u> → one of the metabolites is <u>norpethidine</u> → <u>convulsions</u> (not reversed by <u>naloxone</u>). - <u>Excretion</u>: • As <u>active end products</u> by the <u>kidney</u> so, in <u>renal failure</u> → <u>↑ norpethidine</u> → <u>convulsions</u> • <u>5-10%</u> are excreted <u>unchanged</u> by the <u>kidney</u> and <u>bile</u>.</p>
Action, Side Effects & Contra-indication	<p>- <u>Potency</u>: it is the <u>gold standard</u> against which <u>all other opioids</u> are <u>judged</u>. 1) <u>Analgesia</u>: - Especially for - <u>Somatic</u> and <u>visceral</u> types of <u>pain</u>. - <u>Dull</u> and <u>continuous</u> than <u>sharp</u> and <u>intermittent</u> pain. - Mechanism: • <u>Peripheral anti-nociceptive</u> action. • <u>↑ pain threshold</u>. • <u>↓ psychological</u> and <u>emotional</u> components of <u>pain</u>. - It is augmented by <u>euphoria</u>, <u>drowsiness</u> with <u>↑ dose</u>. It progresses to <u>sleep</u> and eventually <u>anesthetic state</u>. 2) <u>CNS</u>: - <u>Sedation</u> So, it is <u>contraindicated</u> in <u>myxedema</u> as these patients are <u>more sensitive</u>. - <u>Euphoria</u> and <u>hallucination</u> especially in <u>addicts</u> and if there is <u>pain</u>. <u>Dysphoria</u> (<u>mental discomfort</u>, <u>restlessness</u> and <u>malaise</u>) especially in <u>normal subjects</u> with <u>no pain</u>. - <u>Convulsions</u> on <u>high doses</u>. So, <u>contraindicated</u> in <u>epilepsy</u> due to <u>↓ GABA release</u>. 3) <u>Respiratory</u>: - It inhibits <u>cough reflex</u> (<u>anti-tussive action</u>) - It <u>inhibits the respiratory center directly</u> → <u>↓ RR</u> and <u>TV</u> within <u>2-5min</u> after i.v. - <u>CO₂ response curve</u> shifted to the <u>right</u> and with a <u>↓ slope</u> i.e. <u>CO₂ retention</u> → <u>cerebral VD</u> → <u>↑ ICP</u>. So, <u>contraindicated</u> in • <u>pulmonary diseases</u> as <u>emphysema</u>, <u>cor pulmonale</u> • <u>↑ ICP</u> as <u>head injury</u>. 4) <u>CVS</u>: - <u>HR</u>: It occasionally <u>decreases</u> the <u>HR</u> due to <u>vagal center stimulation</u>. - <u>ABP</u>: <u>Little effect</u> in <u>normal supine</u> patient, but <u>↓ in hypovolemic patients</u> or with <u>vasodilators</u>. Due to • (-) <u>vasomotor center</u> → <u>peripheral arteriolar</u> and <u>venous dilatation</u> and <u>↓ VC tone</u>. • <u>Histamine release</u> So, <u>contraindicated</u> in <u>hypovolemic patients</u>.</p>	<p><u>1/10 potency</u> of <u>morphine</u> 1) <u>Analgesia</u>: As <u>morphine</u> 2) <u>CNS</u>: - <u>Sedation</u> - <u>Euphoria</u>: <u>less</u> - <u>Convulsions</u> and <u>hyper-excitability</u> in <u>toxic doses</u> by <u>norpethidine</u> 3) <u>Respiratory</u>: - <u>No action on cough reflex</u> - It <u>inhibits respiratory center directly</u> to the <u>same degree</u> as <u>morphine</u> in <u>equipotent doses</u>. 4) <u>CVS</u>: - <u>HR</u>: <u>↑ anti-cholinergic (atropine-like) action</u> because its <u>structure</u> is <u>similar</u> to <u>atropine</u>. - <u>ABP</u>: not affected, but <u>↓ in hypovolemic patients</u> due to <u>arteriolar and venous VD</u> - <u>Mild quinidine like action</u> → <u>↓ myocardial excitability</u> → <u>↓ incidence of ventricular arrhythmias</u>. This may be related to <u>local anesthetic action</u> of <u>pethidine</u></p>

Fentanyl	Alfentanil	Sufentanil	Remifentanil
<ul style="list-style-type: none"> - Synthetic pure agonist at μ receptors - It is related structurally to (derivatives of) pethidine 	<ul style="list-style-type: none"> - Synthetic pure agonist at μ receptors - It is related structurally to fentanyl 	<ul style="list-style-type: none"> - Synthetic pure agonist at μ receptors - It is related structurally to fentanyl 	<ul style="list-style-type: none"> - Synthetic pure agonist at μ receptors - The only ester structure opioid
<ul style="list-style-type: none"> - Lipid solubility: (++++) → very rapid onset 1-2 min - Duration: <ul style="list-style-type: none"> • 20-30min after single bolus due to redistribution • 2-5hrs after high dose or infusion (up to 9hrs in elderly) due to elimination - Protein binding: (+++) - Metabolism: <ul style="list-style-type: none"> • In the liver → inactive metabolites - Excretion: <ul style="list-style-type: none"> • As water soluble end products by the kidney • Small % excreted unchanged by the kidney and bile 	<ul style="list-style-type: none"> - Lipid solubility: (+++) → very rapid onset (one arm brain circulation time after i.v) - Duration: 5-10min So, it is used as i.v infusion - Protein binding: (++++) - Metabolism: as fentanyl - Excretion: as fentanyl 	<ul style="list-style-type: none"> - Lipid solubility: (+++++) → very rapid onset (more than fentanyl) - Duration: Slightly shorter than fentanyl - Protein binding: (++++) - Metabolism: as fentanyl - Excretion: as fentanyl 	<ul style="list-style-type: none"> - Lipid solubility: (+++++) → very rapid onset - Duration: Ultra-short due to rapid metabolism (not due to redistribution) - Protein binding: (+++) - Metabolism: It is rapidly hydrolyzed by non-specific red cell and tissue esterase as it is an ester. So, it is not affected by renal or liver diseases or plasma cholinesterase deficiency
<p>100 times more potent than morphine</p> <ol style="list-style-type: none"> 1) Analgesia: As morphine 2) CNS: Sedation: less than morphine and pethidine 3) Respiratory: - It inhibits the respiratory center directly for several minutes. It may need mechanical ventilation with large doses or i.v infusion. - I.v bolus may → delayed respiratory inhibition due to its sequestration in gastric juice and subsequent absorption from the small intestine due to high lipid solubility. - Muscle rigidity. 4) CVS: - HR and ABP: are slightly decreased due to vagal stimulation. 5) Nausea and vomiting: - Similar degree as that of other opioids. 6) Smooth muscle: - ↑ tone → spasm of sphincter of oddi and ureter So, it is avoided in 7) Histamine release: Less than morphine 8) Chest wall muscle rigidity: - Especially with large doses → difficult artificial ventilation. 	<p>20 times more potent than morphine</p> <ul style="list-style-type: none"> - Similar to fentanyl action except; 1) CVS: - it inhibits CVS (↓ ABP & HR) more than fentanyl especially in elderly and critically ill patients 2) It interacts with erythromycin: After 7 days erythromycin course, it impairs alfentanil metabolism → ↑ sedation & ↑ respiratory depression 	<p>600 times more potent than morphine</p> <ul style="list-style-type: none"> - Similar to fentanyl action 	<p>100 times more potent than morphine</p> <ol style="list-style-type: none"> 1) Analgesia: - Intra-operatively to; • Supplement general anesthesia → ↓ their doses (volatile and i.v anesthetics) • As a part of i.v sedation • When rapid recovery is needed as in day case anesthesia or • In neurosurgery due to wakeup test and rapid recovery 2) CNS: - It does not produce loss of consciousness - No ↑ ICP or convulsions 3) Respiratory: - It inhibits the respiratory center directly in a dose related manner - Muscle rigidity. 4) CVS: - It is effective in blunting pressor response to intubation - Mild bradycardia.
<ol style="list-style-type: none"> 1) IV route: - For intraoperative analgesia: 1-2 $\mu\text{g/kg}$ - For major surgery (with volatile agents): It is increased up to 150 $\mu\text{g/kg}$ This large dose → • Totally (-) the metabolic response of anesthesia and surgery (i.e. ↑ plasma glucose, cortisol, GH...etc) • It needs postoperative controlled ventilation for some hrs. 2) Trans-dermal (patch) route: - For postoperative pain and cancer pain. 3) Oral trans-mucosal route: e.g. fentanyl lollipop 4) Epidural route: same as i.v dose. 5) Intrathecal (spinal) route: 1/10 of i.v dose 6) Intranasal route: It is used in children as premedication as no need for patient's cooperation. Its onset is within 5 min. 	<ol style="list-style-type: none"> 1) IV route: - For intraoperative analgesia 5 $\mu\text{g/kg}$ - For major surgery (with mechanical ventilation planned) loading 8-100 $\mu\text{g/kg}$ then i.v infusion 0.5-3 $\mu\text{g/kg/min}$ 	<ol style="list-style-type: none"> 1) IV route: - For intraoperative analgesia 0.05 $\mu\text{g/kg}$ - For major surgery (with mechanical ventilation planned) 10-30 $\mu\text{g/kg}$ 	<ol style="list-style-type: none"> 1) IV infusion: Loading 1.0 $\mu\text{g/kg}$ Then followed by 0.5-20 $\mu\text{g/kg/min}$

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	Morphine	Pethidine (Meperidine)
Action (cont.)	<p>5) Nausea and vomiting:</p> <ul style="list-style-type: none"> - They occur some <u>hours</u> after <u>administration</u> and persists for <u>6-8hrs</u>. - they are the <u>most common postoperative</u> complaint. - Similar to <u>other opioids</u> in <u>equi-analgesic</u> doses. - Due to • (+) of <u>chemoreceptor trigger zone</u> <ul style="list-style-type: none"> • Dopamine like action, so; <u>dopamine antagonists</u> e.g. <u>butyrophenones</u> and <u>phenothiazines</u> are effective <u>antiemetics</u> in <u>opioid-induced vomiting</u>. • Vestibular component so; <u>ambulant patient</u> suffers more <p>6) Smooth muscle:</p> <p>a) GIT motility:</p> <ul style="list-style-type: none"> - <u>↓ peristaltic movement</u> → <ul style="list-style-type: none"> - <u>delayed gastric emptying</u> (may <u>↑ vomiting</u>) - <u>constipation</u> on <u>prolonged</u> use due to <ul style="list-style-type: none"> • <u>↓ perception</u> of <u>sensory stimuli</u> of <u>defecation</u>. • <u>↑ tone</u> of <u>sphincter</u> and <u>non-peristaltic movement</u> - <u>↑ non-peristaltic movement</u> → <ul style="list-style-type: none"> - <u>dehiscence</u> of large bowel <u>anastomosis</u>. - <u>↓ absorption</u> of oral drugs <p>b) Uterus: - <u>Prolonged and delayed labor</u></p> <p>c) Sphincters: - <u>↑ smooth muscle tone</u> → <u>↑ sphincter of oddi</u>, <u>ureter</u>, <u>urinary bladder sphincter</u> (→ <u>urine retention</u>)</p> <p>So; avoided in • <u>Biliary</u>, <u>renal colic treatment</u></p> <ul style="list-style-type: none"> • <u>Premedication</u> in <u>cholecystectomy</u> • <u>Prostatic hypertrophy</u> <p>7) Histamine release: →</p> <ul style="list-style-type: none"> • <u>Erythema</u> and <u>pruritis</u> at <u>site of injection</u>. • <u>Hypotension</u>. • <u>Warm and flush</u> sensation. • <u>Bronchospasm</u> so, <u>contraindicated</u> in <u>bronchial asthma</u>. <p>8) Miosis:</p> <p>Due to (+) of <u>Edinger-westphal nucleus</u> of <u>oculomotor nerve center</u>.</p> <p>9) Pregnancy:</p> <ul style="list-style-type: none"> - <u>Prolong labor</u>. - <u>Neonatal respiratory depression</u> as it crosses <u>placenta</u> during <u>labor</u>. - <u>Neonates of chronic use mothers</u> show <u>withdrawal symptoms</u>. <p>10) Endocrine:</p> <ul style="list-style-type: none"> - <u>↑ release</u> of <u>ADH</u>, <u>GH</u> and <u>prolactin</u> - <u>↓ release</u> of <u>ACTH</u>, <u>FSH</u> and <u>LH</u>. <p>11) Metabolic rate:</p> <ul style="list-style-type: none"> - It is <u>inhibited</u> → <u>hypothermia</u> (augmented by <u>VD</u> and <u>↓ muscle tone</u> i.e. <u>heat loss</u>) 	<p>5) Nausea and vomiting:</p> <p>Similar or <u>slightly more</u> than <u>morphine</u>.</p> <p>6) Smooth muscle:</p> <ul style="list-style-type: none"> - <u>↓ GIT motility</u> - <u>↓ tone</u> (i.e. <u>relax</u>) of <u>GIT</u> and <u>renal smooth muscles</u> so; can be used in <u>renal colic</u>. <p>7) Histamine release:</p> <ul style="list-style-type: none"> - <u>Less</u> than <u>morphine</u>. - It may have <u>antihistaminic (H₁)</u> action. <p>So, it can be used in <u>bronchial asthma</u>.</p> <p>8) No miosis</p> <p>9) Pregnancy:</p> <ul style="list-style-type: none"> - It does <u>not prolong labor</u> - <u>Neonatal respiratory depression</u> as it crosses the <u>placenta</u>, but <u>less prolonged</u> than <u>morphine</u> so; it is <u>preferred</u> in <u>obstetrics</u> - <u>Neonates of chronic use mothers</u> show <u>withdrawal symptoms</u>. <p>10) Interaction with MAOIs, L-dopa or tyramine in food:</p> <p>+ opioids especially <u>pethidine</u> → <u>life threatening hypertensive crisis</u>, <u>hyper-reflexia</u>, <u>convulsions</u> and <u>coma</u></p>
Dose & route	<p>It is taken by <u>all routes</u> as <u>morphine sulfate</u> or <u>HCL</u></p> <ol style="list-style-type: none"> 1) <u>I.v.</u> route: <u>0.1 mg/kg</u> up to <u>1 mg/kg</u> for <u>intra-operative analgesia</u> 2) <u>I.m.</u> route: <u>0.2 mg/kg</u> for <u>postoperative analgesia</u>. 3) <u>Oral</u> route: <u>0.4 mg/kg</u> for <u>chronic pain</u> (<u>10-30 mg tablets</u>)(<u>MST</u>) 4) <u>Epidural</u> route: the same as <u>i.v. dose</u> 5) <u>Intrathecal (spinal)</u> route: <u>1/10</u> of <u>i.v. dose</u> 6) <u>Patient-controlled analgesia</u> 7) <u>Rectal</u>. 	<ol style="list-style-type: none"> 1) <u>I.v.</u> route: <u>0.5-5 mg/kg</u> 2) <u>I.m.</u> route: <u>1mg/kg</u> 3) <u>Epidural</u> route: the same as <u>i.v. dose</u> 4) <u>Intrathecal (spinal)</u> route: <u>1/10</u> of <u>i.v. dose</u>

N.B.; The wide range of opioid doses reflects a large therapeutic index and depends upon;

- Other anesthetics simultaneously given.
- Tolerance can develop rapidly (i.e. within 2 hours) during i.v. infusion of opioids, necessitating higher infusion rates.
- Elderly require smaller doses.

For obese patients, the dose should be based on ideal body weight or lean body mass, not total body weight.

Patient- Controlled Analgesia (PCA)

Indications: pain relief after major surgery.

Technique:

- When the patient requests an increment of opioids, he presses a button which in turn, triggers the release of opioid through a venous cannula either from a syringe driver or a simple balloon type reservoir under pressure.
- The delivery system is designed so that, a maximum dose predetermined by the anesthetist is delivered per bolus increment.
- Also, a lock-out interval is selected by the anesthetist, during which no additional doses are delivered.
- Typical regimen: • At first, control any pain by i.v. morphine.
• Then morphine 1 mg increments with a lock-out period of 5 min without background infusion.
- Other opioids as fentanyl i.v., pethidine i.v., tramadol i.v., and dia-morphine s.c. (in terminally ill patients) can be used.
- It is essential to impress upon patients that they are in control of their analgesia and can titrate, within set limits, the amount of i.v. opioids they receive.
- It is essential to ensure supervision of patients with PCA (by nurses and junior medical staff) especially for respiratory depression and airway obstruction.

Contraindications:

- 1- Mental retardation.
- 2- Confusion or debility.
- 3- Patient's refusal as some patients prefer traditional i.m. regimens.

Side effects:

- 1- Nausea, vomiting, and pruritis are very common. They are the most troublesome side effect suffered by the patients.
- 2- Respiratory depression is very rare.

Spinal (Epidural or Intrathecal) Opioids

Mechanism:

- Via opioid receptors in the gray mater of the dorsal horn of the spinal cord.
- But actually systemic absorption occurs causing analgesia centrally which may share in producing the action.

Duration of Blockade:

- Clinically intrathecal opioids produce longer analgesia (and so, smaller doses, less side effects) than epidural opioids.
- Duration is about 6-12 hours after bolus injection.
- Continuous analgesia can be produced by continuous infusion via a catheter.

Dose:

All drugs should be preservative free.

	<u>Intrathecal route</u>	<u>Epidural route</u>
	<u>1/10 of i.v. dose</u>	<u>Nearly the same as i.v. doses</u>
<u>Morphine</u>	<u>0.1-1.0 mg (duration = 6-8 hrs)</u>	<u>1-10 mg (duration = 24 hrs)</u> <u>0.3-0.9 mg/hr</u>
<u>Pethidine</u>	<u>0.1 mg/kg up to 10 mg total</u>	<u>0.75-1 mg/kg up to 100 mg total</u>
<u>Fentanyl</u>	<u>0.1-0.2 µg/kg</u>	<u>1 µg/kg bolus or 1-2 µg/kg/hr</u>

PHARMACOLOGY OF ANESTHESIA

Side Effects: (dose related)

① Respiratory Depression:

- Especially with • Relative lipid insoluble drugs (e.g. morphine).
 - Old age.
 - Concomitant systemic opioid administration.
- Two types of respiratory depression may occur;
 - Within 1 hour due to systemic absorption.
 - Within 6-12 hours due to cerebral migration.
- Therefore, patients should be supervised for at least 12 hours after the last dose of opioid in a high dependency unit (equipped with pulse oximetry and ECG monitoring).

② Urine Retention:

- Especially with • Subarachnoid > epidural.
 - Men > 90 %.

③ Pruritis:

- Especially with • epidural morphine in 70-80% of patients

④ Nausea and vomiting:

- It is the most common and most troublesome side effect suffered by the patients.

⑤ Hypotension.

N.B.; Patient Controlled Epidural Analgesia: See later.....

Opioid Antagonists

Mechanism of Action:

By competitive antagonists at opioid receptors, their affinity for μ receptors appears to be much greater than for kappa and delta receptors.

Naloxone

Chemical structure:

It is related to oxy-morphine.

Onset: Within 1 min (after i.v. route).

Duration: 20-30 min.

Clinical Actions and Uses:

It antagonizes all the CNS effects of opioid agonists including analgesia as;

① Opioid-induced ventilatory depression:

- In low doses, therefore, the drug should be titrated slowly against the clinical effect to avoid antagonizing analgesia.
- It is of relatively short duration so, it may cause returning of respiratory depression induced by longer-acting opioids so, patients should be monitored carefully for an appropriate period after its use.
- It is of choice in neonates so, it is used in neonatal respiratory depression (asphyxia neonatorum).

② Opioid-induced coma or excessive sedation:

- Therefore, it is used in treatment of poisoning of morphine and morphine- like drugs. Also, it is used in diagnosis of dependence on opioids (withdrawal symptoms occur).

③ Opioid-induced analgesia:

- In large doses, it antagonizes analgesia even analgesia of spinal cord causing pain that may stimulate sympathetic system producing increase of HR, BP, and arrhythmias.

N.B.; - Naloxone is ineffective in ventilatory depression or sedation caused by;

- Buprenorphine due to very high affinity of buprenorphine to μ receptors.
- Non-opioid drugs e.g. barbiturates or benzodiazepines.

- Naloxone may antagonize the antihypertensive effect of clonidine.
- Naloxone can be used to improve circulation in refractory shock.

Dose: (Ampoule = 0.2 or 0.4 mg/mL)

- ① I.v. bolus: - Increments of 0.5-1 µg/kg every 3-5 min (usually 0.2-0.4 mg in adult).
- Supplementary doses may be required after 20-30 min.

- ② I.v. infusion: 4-5 µg/kg/hr

- ③ I.m.: Twice i.v. dose, with longer duration of action.

N.B.; • Neonatal respiratory depression resulting from maternal opioid administration is treated with 10 µg/kg.

- Neonates of opioid-dependence mothers will exhibit withdrawal symptoms if given naloxone.

To remember doses of the anesthetic drugs;

- Most of anesthetic drugs are presented from the manufacturing companies as one ampoule or vial for one dose for a 70 kg adult so, if you divide the content of the ampoule on 100 this will give you usually the minimal dose of drug /kg.

E.g.:

			minimal dose /kg
• <u>Thiopentone vial</u>	= <u>500 mg</u>	→	<u>5 mg/Kg.</u>
• <u>Propofol ampoule</u>	= <u>200 mg</u>	→	<u>2 mg/Kg.</u>
• <u>Atropine ampoule</u>	= <u>1 mg</u>	→	<u>0.01 mg/Kg.</u>
• <u>Suxamethonium ampoule</u>	= <u>100 mg</u>	→	<u>1 mg/Kg.</u>
• <u>Fentanyl ampoule</u>	= <u>100 µg</u>	→	<u>1 µg/Kg</u>
• <u>Morphine ampoule</u>	= <u>10 mg</u>	→	<u>0.1 mg/kg</u> <u>i.v. route.</u>
	= <u>20 mg</u>	→	<u>0.2 mg/kg</u> <u>i.m. route.</u>
• <u>Pethidine</u>	= <u>50 mg</u>	→	<u>0.5 mg/kg</u> <u>i.v. route.</u>
	= <u>100 mg</u>	→	<u>1 mg/kg</u> <u>i.m. route.</u>
• <u>Ketamine vial</u>	= <u>10 mL (50 mg/ml)</u> = <u>500 mg</u>	→	<u>5 mg/Kg</u> <u>i.m. route.</u>
• <u>Prostigmine (in reverse)</u>	= <u>2mL i.e. 5 mg</u>	→	<u>0.05 mg/Kg.</u>
• <u>Atracurium big ampoule</u>	= <u>50 mg</u>	→	<u>0.5 mg/Kg. (initial dose).</u>

N.B.; A small ampoule of atracurium = 25 mg is used for maintenance doses.

- Pancuronium (Pavulon): It is provided in 4 mg ampoule. So, 2 ampoules = 8 mg → 0.08 mg/Kg as initial intubating dose. This is because it is a long acting drug so, if it is provided as 8 mg ampoule the user will give on maintenance doses only 1-2 mg (usual period of operations is 1 hr) so, there will be a large amount which will not be used and discarded (about 6-7 mg) so, companies provide it in maintenance ampoules. (the same with pipecuronium).

- " **Warning !!** you must give the suitable dose of each drug for each patient e.g. in opioids, you must increase the dose if severe pain is suffered and decrease the dose in elderly or liver disease.

This is only just my observation on drug presentation.

CHAPTER 4

AIRWAY MANAGEMENT

AIRWAY

Indications:

- **Loss of upper airway muscle tone** (e.g. genioglossus) in anesthetized patients leads to the fall back of the tongue and the epiglottis against the posterior wall of the pharynx. Therefore, insertion of an artificial airway creates an air passage between the tongue and the posterior pharyngeal wall (figure 4-1).
- **It prevents biting of the tube by the patient** during awakening from anesthesia by oral types.

Types:

1- Oro-pharyngeal Airway (of Guedel):

- There are many sizes 00, 0, 1, 2, 3, 4.
- The distance between the tip of the nose and the earlobe approximates the correct length of an oral airway (figure 4-2).**
- It may cause cough or even laryngospasm if the laryngeal reflexes are intact in awake or lightly anesthetized patient.
- **Cuffed Oro-pharyngeal airways (COPA):** It is recently invented. It can be connected to breathing circuits to supply anesthesia as it has the standard 15 mm connector. It has a large oral cuff.

2- Nasopharyngeal Airway:

- It is 3-4 cm longer than an oral airway.
- It is **better tolerated** than the oral types in lightly anesthetized patients.
- It is **more traumatizing** especially in **anticoagulated patients or in children with prominent adenoids** so, it should be **lubricated** and advanced in an angle perpendicular to the face (figure 4-3).



Figure 4-1; Loss of airway muscle tone in an anesthetized patient causing airway obstruction

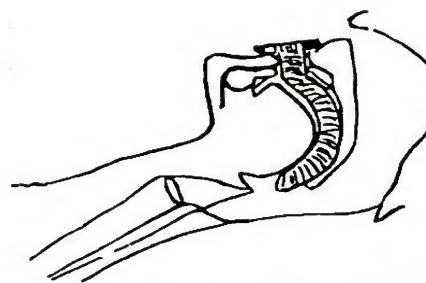


Figure 4-2; Oro-pharyngeal airway

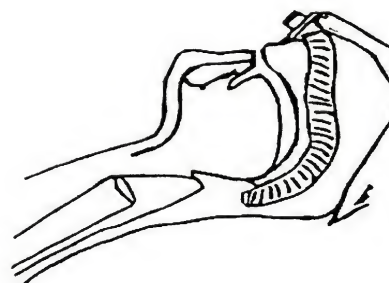


Figure 4-3; Nasopharyngeal airway

FACE MASK

Design:

- The rim of the mask is contoured and conforms to a variety of facial features allowing air-tight seal.
- **Transparent bodies** allow observation of **exhaled humidified gas** and immediate recognition of **vomiting**.
- **Retaining hooks** surrounding the 22-mm orifice can be attached to a head strap "**harness system**" e.g. **Clausen harness**, allowing the mask to be held in place without the need of anesthesiologists (figure 4-4).
- The smallest size possible should be used to decrease the size of dead space. Some pediatric masks are especially designed (with shallow body) to decrease apparatus dead space as the **Rendell-Backer- Soucek pediatric face mask** (figure 4-5).

Technique:

a- One-handed face mask technique:

- By holding the mask with the left hand thus, allowing the right hand to generate positive pressure ventilation by squeezing the breathing bag.
- The mask is held against the face by the left thumb and index finger while the middle and ring fingers grasp the mandible to extend the atlanto-occipital joint.
- Finger pressure should be placed on the bony mandible and not on the soft tissues supporting the base of the tongue otherwise, the airway will be obstructed especially in pediatrics.

- The little finger slides under the angle of the jaw and thrusts it anteriorly (figure 4-6).

b- Two-handed face mask technique:

- In difficult situations as edentulous patients. So, leaving dentures in place or packing the buccal cavity with gauze may help.
- Two hands holding the mask to provide adequate jaw thrust (i.e. holding the mandible forward) and create a mask seal. Therefore, an assistant may be needed to squeeze the breathing bag.

- In this case, the thumbs hold the mask down while the finger tips or knuckles displace the jaw forward (figure 4-7).

c- Three-handed face mask technique:

- The anesthesiologist by his two hands and the assistant by one hand hold the mask while the other hand of the assistant is needed to squeeze the bag (figure 4-8).



Figure 4-4; An adult face mask

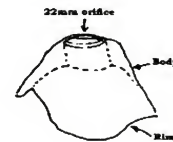


Figure 4-5; Rendell-Backer- Soucek mask



Figure 4-6; One-handed technique



Figure 4-7 Two-handed technique



Figure 4-8; Three-handed technique

AIRWAY MANAGEMENT**Laryngeal Mask Airway (LMA)**

It is developed by Dr. Archie Brain (1988) (British)

- Design:

- It is reusable, made of silicone rubber (i.e. latex-free) and autoclavable.
- It consists of a wide-bore tube whose proximal end connects to a breathing circuit with a standard 15 mm connector and whose distal end is attached to an elliptical cuff which is inflated by a pilot tube (Figure 4-9).

N.B.; Diameters of anesthetic connections:

- 15 mm → ETT connector.
- 22 mm → Mask connector.
- 30 mm → Scavenging system connector.

- Size:

Mask Size	Weight of The Patient	Cuff Volume
1	< 5 kg infant	2 - 4 ml
1.5	5 -10 kg child	4 - 7 ml
2	10 -20 kg child	up to 10 ml
2.5	20 -30 kg child	up to 15 ml
3	30 -70 kg small adult (female)	up to 20 ml
4	> 70 kg normal adult (male)	up to 30 ml
5	> 90 kg large adult	up to 40 ml

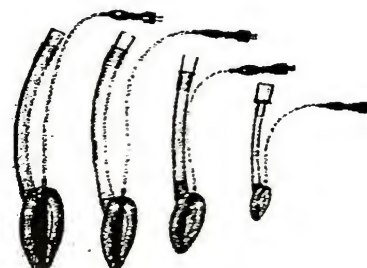


Figure 4-9; LMA

- Types:

- 1- Classic (standard) LMA.
- 2- Flexible LMA.
- 3- Disposable (unique) LMA.
- 4- LMA-Fastrach (intubating) (figure 4-10):

Where the two bars at the aperture of the regular LMA have been replaced by a single, movable epiglottic elevating bar (EEB) that allows a smooth and unobstructed passage of ETT as it emerges from the metal shaft of the LMA-Fastrach. The metal shaft of the LMA-Fastrach allows the insertion of up to 8.5 mm ID ETT. The shaft is shorter in length, thus eliminating the need for longer ETT in patients with long necks.

5- Gastric (Proseal) LMA (PLMA):

It is with a modified posterior cuff to improve laryngeal seal so, allow high +ve pressure application. There is also a 2nd channel for gastric tube placement or passage of regurgitated fluid so, protect airway against aspiration (Figure 4-11).

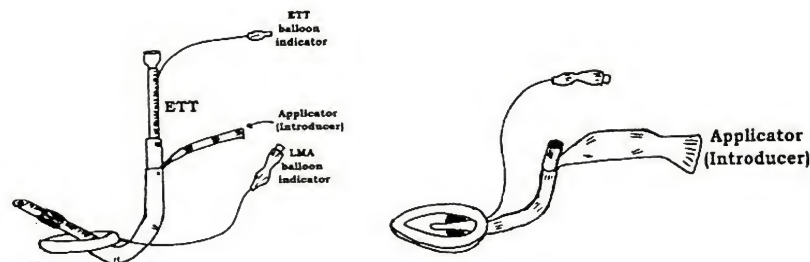


Figure 4-10; Fastrach LMA

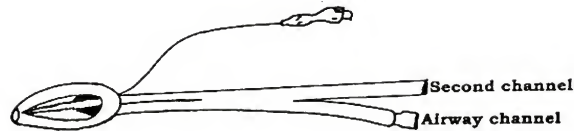


Figure 4-11; PLMA

- **Technique:** (Figure 4-12)

- After choosing the appropriate size and **checking** for cuff leaks before insertion, leave the cuff either **deflated or partial deflated**.
- **Lubricate** only the back side of the cuff.
- Ensure adequate anesthesia.
- Place the patient's head in **sniffing position**.
- Hold LMA in the hand "**like holding a pen**" with your index finger to guide the cuff along the hard palate and down into the hypopharynx until a resistance is felt.
- The longitudinal black line should always be pointing directly cephalad (i.e. facing the patient's upper lip).
- **Inflate** with the correct amount of air as shown.
- Correct position is indicated by movement of patient's chest with gentle manual inflation or movement of the bag with patient breathing.
- Obstruction after insertion is usually due to
 - A down-folded epiglottis or distal cuff.
 - Transient laryngospasm.
- In difficult cases, LMA insertion under direct visualization with a laryngoscope or fiberoptic bronchoscope may prove beneficial.
- LMA is secured (to the middle of lips) with a tape or bandage.

N.B.; The ease of LMA insertion **does not correlate**

with Mallampati grade. It appears that the position of the larynx has little bearing on the LMA insertion. It has been suggested that the presence of an anterior larynx may make the LMA insertion easier.

- **Removal of LMA:** - It should be removed either when the patient is **deeply anesthetized** or after they have **awakened** and their airway reflexes are intact.

- The cuff of the LMA may be either;

- Deflated before removal.

Or • Left fully inflated to scoop out the secretions above the mask as it is withdrawn.

- **Indications:**

a- Instead of the face mask, in minor procedures so, no need for the anesthesiologist's hand to support the mask.

b- Instead of the endotracheal tube, (for spontaneous ventilation).

1. No **pressor response** of intubation so, it is preferred in patients with ischemic heart diseases or hypertensive patients.
2. Allow smooth induction and recovery so,
 - It decreases the risk of increased **IOP** so, it is used in intraocular procedures.
 - It decreases risk of increased **ICP** so, it is used in neurosurgery.
3. Less invasive than intubation so, it is preferred in **outpatient anesthesia**.

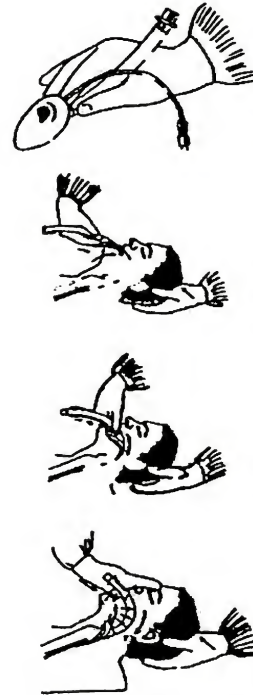


Figure 4-12; Technique of LMA insertion

AIRWAY MANAGEMENT

N.B.; It can be used for mechanical ventilation with keeping airway pressure between 15-20 Cm H₂O to avoid gastric insufflation and oropharyngeal leak.

C- In difficult intubation:

- It is used **as an airway** in case of "can not intubate ,can not ventilate " because of its ease of use (success rate up to 99%).
- It is used **as a conduit** for an intubating stylet, bougie, ventilating jet stylet, flexible fiberoptic bronchoscope or smaller diameter tubes (6.0 mm).
- It is used in **patients with cervical spine injury** because it can be applied in the neutral position.

- Contraindications:

- 1- **Pharyngeal** (glottic or subglottic) pathology as abscess, surgery or obstruction.
- 2- **Full stomach** or causes of delayed gastric emptying e.g. obstetrics, hiatal hernia or esophageal reflux.
- 3- High airway resistance e.g. **bronchospasm**.
- 4- **Low pulmonary compliance** e.g. obesity.

Both 3 and 4 require peak inspiratory pressure > 20 cm H₂O which could increase gastric distension.

- 5- One lung ventilation.

- Complications:

- 1- **Inflation of the stomach** especially when
 - Peak inspiratory pressure exceeds 20 cm H₂O.
 - Esophagus lies within the rim of the cuff.

Both **increase the risk of regurgitation**.

Incidence of regurgitation with LMA is 2: 10 000

Incidence of regurgitation with E.T.T is 1.7: 10 000 i.e. nearly the same.

- 2- **Sore throat** in 4-12 % of patients.
- 3- **Coughing and laryngospasm** (as oropharyngeal airways).
- 4- **Risk of airway obstruction** in 25-50 % of pediatrics and 10 % of adults due to down-folding of epiglottis or distal end of the cuff.
- 5- **Trauma to the airway** (pharyngeal or laryngeal).

Esophageal-Tracheal Combitube

- Design:

- It consists of two fused tubes, each with a 15 mm connector on its proximal end:
 - The longer tube (blue) has an occluded distal tip that forces gas to exit through a series of side perforations.
 - The shorter clear tube has an open tip and no side perforations.
- There are two inflatable cuffs 100- cc proximal cuff and 15- cc distal cuff.

- Technique: (Figure 4-13)

- The combitube is usually **inserted blindly** through the mouth and advanced until the two black rings on the shaft lie between the upper and lower teeth.
- The 2 cuffs should be fully inflated after placement.
- Two possibilities are present after insertion of the tube; either;
 - a- Inserted **into** the esophagus, so, ventilation via the blue tube (1) will force gases out the side perforations and into the larynx. The other tube (2) can be used for gastric decompression (this is the more common possibility 99%).
 - b- Inserted into trachea, so, ventilation through the clear tube will direct gas into the trachea.

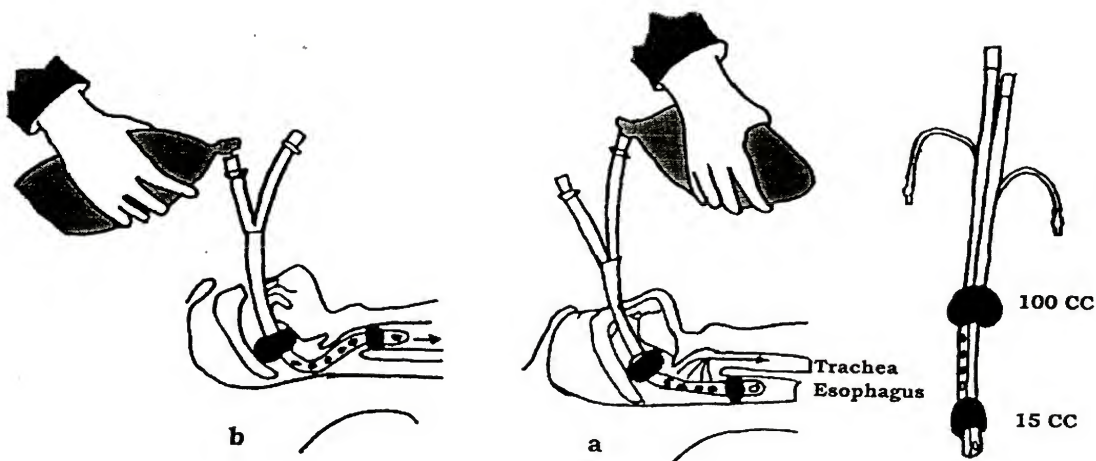


Figure 4-13; The combi-tube

- Contraindications:

1. Esophageal pathology or a history of caustic substance ingestion.
2. Patients with an intact gag reflex.
3. Glottic or subglottic pathology as spasm, massive edema, tumor, abscess or hematoma.

N.B.; **Supra-laryngeal devices** for ventilation include;

a- Mask ventilation.

b- **Supra-laryngeal airway devices;** 1- Combi-tube.

2- LMA.

3- COPA.

4- Nasopharyngeal airway.

5- Oro-pharyngeal airway.

6- Laryngeal tube.

Endotracheal Tubes (E.T.T.)

- Design: (Figure 4-14)

- It is made of - Polyvinyl chloride (PVC) → disposable (most common).
or - Red rubber → reusable and autoclavable.
- Tracheal tubes marked I.T. or Z-79 is implant-tested to ensure non-toxicity.
- A hole (**the Murphy eye**) is present to decrease the risk of complete tube occlusion.
- E.T.T. size is usually designated in millimeters of internal diameter (or less commonly in the French scale) (External diameter in millimeters multiplied by 3)
- Most adult E.T.T have a cuff inflation system consisting of a valve, pilot balloon, inflating tube, and cuff. The valve prevents air loss after cuff inflation. The pilot balloon provides a gross indication of cuff inflation.
- The cuff creates a seal allowing +ve pressure ventilation and decreases the risk of aspiration. Uncuffed tubes are usually used in children to decrease the risk of pressure injury and post-intubation croup, because the cuff is not needed as the larynx is funnel shaped in pediatrics with the narrowest part at the cricoid cartilage (in adults, the vocal cords are the narrowest part).

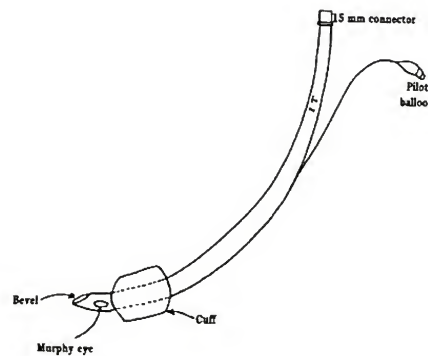


Figure 4-14; ETT

AIRWAY MANAGEMENT**- Types of Cuffs:** (Figure 4-15)**a- High pressure (low volume) cuff:**

- Although it produces more better seal, but it produces more severe ischemic damage to the tracheal mucosa so, it is less suitable for long operations.

b. Low pressure (high volume) cuff:

- Although it produces more sore throat (as larger mucosal contact area), aspiration, spontaneous extubation and difficult insertion (due to floppy cuff), but it produces less severe ischemic damage to the tracheal mucosa so, it is more recommended especially for lengthy operations.

- Cuff pressure depends on:

1. Inflation volume.
2. The diameter of the cuff in relation to the trachea.
3. Tracheal and cuff compliance.
4. Intrathoracic pressure (as cuff pressure increases with coughing).
5. N₂O diffuses from the tracheal mucosa into the cuff causing increase of cuff pressure so, readjust cuff volume after 10-15 min or fill the cuff with O₂/N₂O mixture.

- Specialized tube types:

1. **Armored tube:** flexible, spiral-wound, wire-reinforced E.T.T.

- Advantages: It resists kinking so, used in head and neck surgery or in abnormal positions as prone position.

- Disadvantages: If it is kinked by extreme pressure e.g. an awake patient biting it, the lumen will tend to remain occluded and the tube will need replacement.

2. **Micro-laryngeal tubes.**

3. **RAE performed tubes (oral and nasal)** (figure 4-16).

4. **Oxford tube:** It is L-shaped where the angle of the tube lies in the pharynx, the distal end is of a fixed length (figure 4-17). So, it has advantages:

- decreased risk of bronchial intubation.
- decreased risk of kinking with flexed head during surgery.

5. **Double lumen E.T.T.**

6. **E.T.T. for laser.**

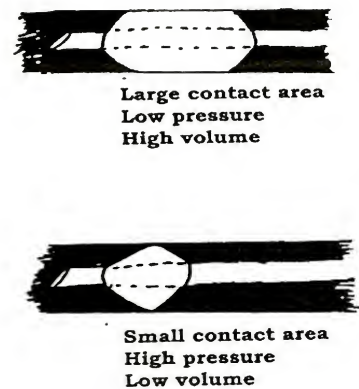


Figure 4-15; Types of cuffs

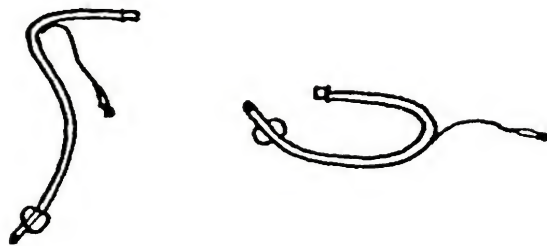
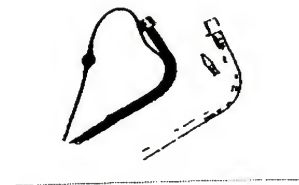


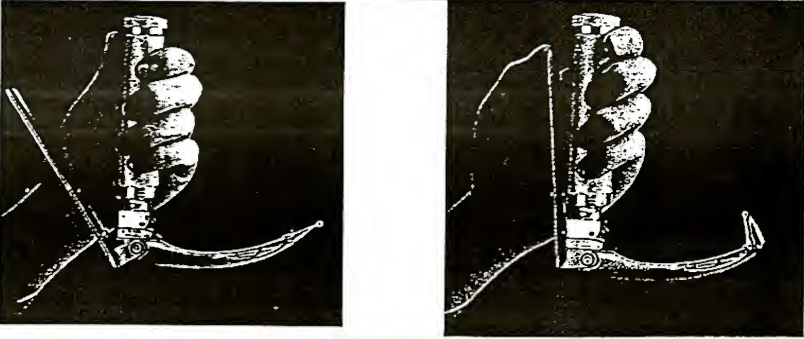
Figure 4-16; RAE performed tubes;
Nasal (left), oral (right).

Figure 4-17; Oxford tracheal tube

Rigid Laryngoscopes

- It is an instrument used for
 - Direct examination of larynx.
 - Intubating the trachea.

- **Types of blades:** (figure 4-18)

Macintosh blade (curved) (the most common) There are 4 sizes.		
Miller blade (straight) There are 4 sizes		
McCoy Flap tip blade		

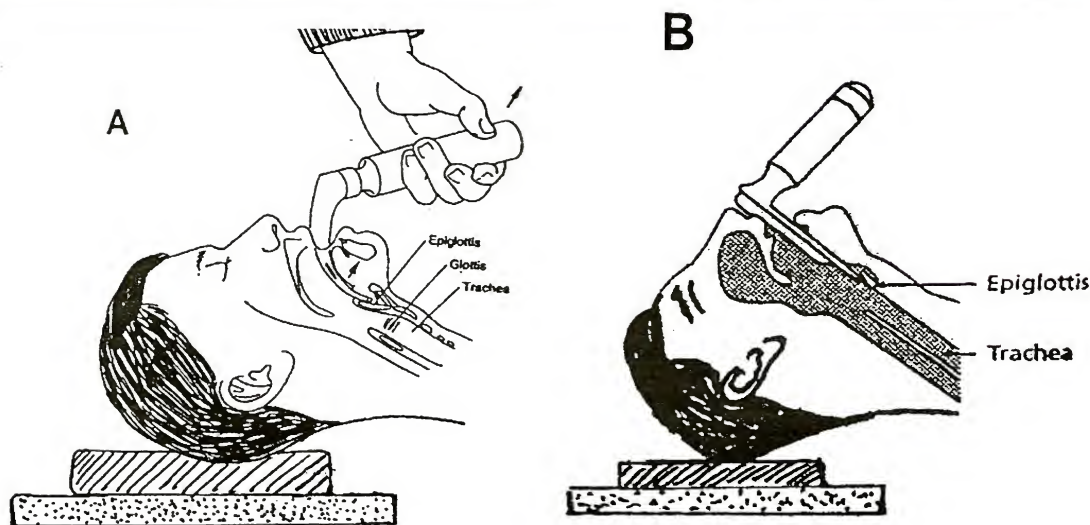


Figure 4-19; Endotracheal intubation using a curved Macintosh laryngoscope blade (A) and a straight Miller laryngoscope blade (B)

	Macintosh	Miller
Shape	- Curved	- Straight
Technique	- It is introduced to the base of epiglottis then it is elevated forward to elevate the epiglottis. - It touches the upper surface of epiglottis (supplied by glosso-pharyngeal nerve) (figure 4-19).	- It touches the lower surface of epiglottis (supplied by vagus)
Indication	- Patients with little upper airway room to pass E.T.T. e.g. small narrow mouth, palate	- Patients with small mandibular space (i.e. anterior larynx), large incisors long floppy

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	or oropharynx.	epiglottis.
Disadvantages	- It is useless with large floppy infantile u-shaped epiglottis.	- As it touches the lower surface of the epiglottis, it stimulates the vagus causing bradycardia and spasm. Therefore, anticholinergics are essential before its usage.

Indications of Intubation:

1. Provision of clear **airway** e.g. anticipated difficulty in using mask anesthesia in an edentulous patient.
2. An **unusual position** anesthesia e.g. prone, sitting.
3. **Head and neck surgery.**
4. **Protect respiratory tract against aspiration**, blood during oral or upper respiratory tract surgery.
5. During need for **IPPV** and muscle relaxants.
6. To facilitate **suction** from the respiratory tract.

Technique of Intubation:**A. Preparation For Rigid Laryngoscopy:**● Checking equipment:

1. **E.T.T. examined for;**
- Choose the proper size + one size above and one size below.

Age	Internal diameter (mm)	Length at lips (cm)
Full-term infant	3.5	10
Child	Age / 4 + 4	Age / 2 + 12
Adult		
- Female	7.0 -8.0	19 - 21
- Male	8.5 -9.5	21 - 22

- The tube's cuff inflation system can be tested.
 - Some anesthetists cut the E.T.T. to a preset length to decrease the risk of endo-bronchial intubation or occlusion from tube kinking.
 - If a stylet is used, it should be inserted into the E.T.T. which is bent to resemble a hockey stick to facilitate intubation of an anteriorly positioned larynx.
 - Check the patency of the tubes especially rubber reusable tubes.
2. **The laryngoscope should be examined for;**
- Proper blade size.
- Light intensity is tested as it should remain constant (a blinking light indicates poor electrical contact, while fading indicates low batteries).
- Spare laryngoscope should be prepared.
 3. **Suctioning unit:** a proper functioning unit should be available.

● Patient preparation:

1. The patient's head should be at level with the anesthesiologist's xiphoid process to prevent unnecessary back strain during laryngoscopy. Put the patient's head in **sniffing position** by 10 cm pillow to flex the neck and extend the head. This position makes the larynx in the same line with mouth i.e. it flexes the lower cervical spine and extends the atlanto-occipital joint (figure 4-20).

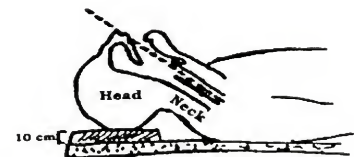


Figure 4-20 Sniffing position

2. Preoxygenation with 100 % O₂ by several deep breathes is done. It can be omitted in patients who refuse the face mask and who are free of pulmonary diseases.
3. Protect patient's eyes by routinely taping the eye shut often after applying a petroleum-based ophthalmic ointment.

B. Oro-tracheal Intubation:

- The laryngoscope is usually held in the non-dominant hand (usually the left). With the patient's mouth opened widely, the blade is introduced into the right side of the oropharynx with care to avoid the teeth.
- The tongue is swept to the left and up into the floor of the pharynx by the blade's flange.
- The tip of a curved blade is usually inserted into the vallecula, while the straight blade tip covers the epiglottis especially in children, this surface is supplied by the vagus so vagal stimulation causes more bradycardia.
- With either blades, the handle is raised up and away from the patient in a plane perpendicular to the patient's mandible to expose the vocal cords. Avoid leverage of the teeth.
- Take the E.T.T. with the right hand and its tip is passed through the abducted vocal cords.
- E.T.T.'s cuff should lie in the upper trachea but beyond the larynx.
- The laryngoscope is withdrawn, again with care to avoid teeth damage.
- The cuff is inflated with the least amount of air necessary to create a seal during +ve pressure ventilation (feeling the pilot balloon is not a reliable method of determination of adequacy of cuff pressure).
- Immediately after intubation, the chest and epigastrium are auscultated and capnographic tracing is monitored to ensure intra-tracheal location.
- The tube is taped to secure its position.

C. Naso-Tracheal Intubation:

- It is similar to oral intubation, but the tube is advanced via the nose into the oropharynx before laryngoscopy. The right nostril is usually preferred as the left facing bevel of the tube favors this side. If the right nostril is blocked e.g. deviated septum so, use the left nostril.
- Phenylephrine nasal drops (0.5% or 0.25%) causes VC of vessels causing shrink of mucous membrane.
- E.T.T. is lubricated with water-soluble jelly and introduced along the floor of the nose below the inferior turbinate, at an angle perpendicular to the face till it is seen in the oropharynx where the laryngoscope is used.
- Magill forceps (pediatric or adult size) can be used to facilitate passage of the tip of the tube through the vocal cord or just head flexion can be helpful (Figure 4-21).

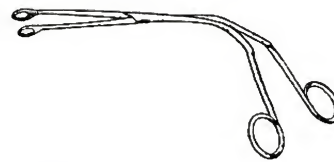


Figure 4-21; Magill forceps

D. Flexible Fiberoptic Intubation:

- Available for adult and pediatric sizes.
- Flexible fiberoptic bronchoscope has 3 bundles;
 - 2 bundles of-glass fibers each consisting of 10 000- 15 000 fibers.
- One bundle transmits light from the light source (light source bundle).
- The other bundle provides a high resolution image (image bundle).
 - Aspiration channels for suctioning, insufflating O₂, instilling local anesthetics (figure 4-22).

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- Both nostrils are prepared by vasoconstrictor drops.
- Ensure adequate patient ventilation and oxygenation, confirmed by capnography and pulse oximetry.
- By • O₂ is insufflated via the aspiration channel of the bronchoscope.
- A large nasal airway e.g. I.D. 7-8 can be inserted in the contra-lateral nostril which is connected to a breathing circuit and 100% O₂.
- In unconscious patients (who are not breathing), close the mouth by tape and connect the nasal airway to a breathing circuit for controlled ventilation.
- A lubricated E.T.T. is inserted and advanced in the other nostril.
- Introduce the lubricated bronchoscope via the tube, when its tip passes through the distal end of the endotracheal tube, the epiglottis or glottis should be visible.
- Then the tip of the bronchoscope is manipulated to pass via the abducted cord.
- In difficult cases, having an assistant who thrusts the jaw forward or applies cricoid pressure may improve visualization. Even with good anesthesia, a violent cough occurs when the bronchoscope enters the trachea.
- Once in the trachea, the scope is advanced to within the sight of the carina. The presence of tracheal rings and the carina is a proof of proper positioning, then the E.T.T. is slipped over the fiberoptic shaft.
- Proper E.T.T. position is confirmed by viewing the tip of the tube above the carina before the fiberoptic scope is withdrawn.
- Oral fiberoptic intubation can be also done.

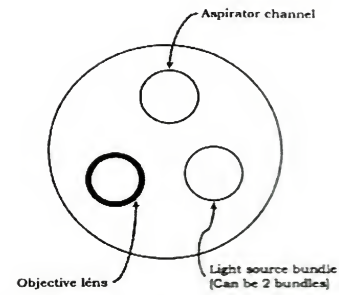


Figure 4-22; Cross- section
in fiberoptic laryngoscope

Indications of fiberoptic intubation:

Cases of difficult intubation. See causes of difficult intubation.

Extubation**Criteria For Extubation:****A- Global Criteria:** include;

- Return of consciousness as - Ability to follow commands e.g. opening the eyes.
- BIS monitor is 90-100.
- Return the ability to protect the airway.
- Adequate reversal of residual NM blockade by clinical tests and nerve stimulators
- Absence of hypothermia.
- Presence of normal metabolic milieu (e.g. no significant anemia, acidosis, and electrolyte abnormality).
- Stable hemodynamic status.

B- Respiratory Criteria: include;

- Spontaneous breathing.
- Regular respiratory rate and less than 30 breath/min.
- Adequate tidal volume > 5 mL/Kg.
- Adequate vital capacity > 10-15 mL/Kg.
- Negative inspiratory force (and airway pressure) is less than -20 to -30 cm H₂O.
- AB gases on FiO₂ less than 0.4 are - pH 7.35-7.45
- PaO₂ > 60-80 mm Hg.
- SpO₂ > 90 %
- PaCO₂ < 50 mm Hg

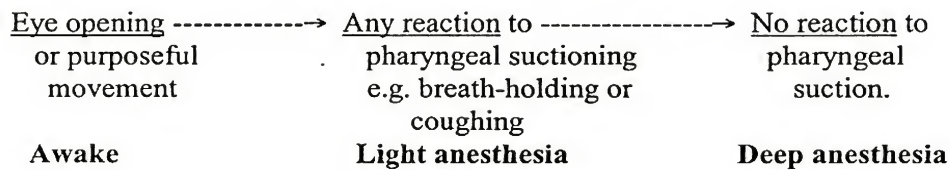
For more detailssee intensive care.

Technique:**1- Suctioning the pharynx before extubation:**

- Oropharyngeal suctioning is done from the most dependent part, but it is best done suction under vision to avoid trauma to pharyngeal mucosa, uvula or epiglottis.
- It decreases the risk of aspiration and laryngeal spasm.
- Tracheobronchial suctioning may be done by soft sterile suctioning catheter with a diameter less than the internal diameter of the tube.
- Then un-tape the tube, deflate the cuff completely just before extubation.

2- Time of extubation:

- It is part of the art of anesthesiology that develops with experience.
- Generally,
 - Adequate recovery from muscle relaxant should be established before extubation.
 - Extubation is done during either deep anesthesia or total awakesness (**avoided during light plane of anesthesia i.e. between deep and awake states as during light anesthesia, there is an increased sensitivity of reflexes which increases the risk of laryngospasm**).

**3- Types of Extubation:****a- Awake Extubation:**

- It is done when the patient is fully awake.
- Indications:
 - Generally, **all anesthetized patients** should be extubated awake.
 - Patients at risk of aspirations i.e. **full stomach** (empty the stomach with an oropharyngeal tube while the patient is still paralyzed).
 - Patient's with airways which may be **difficult to control after E.T.T. removal**.
- Effects: Coughing (bucking) on E.T.T. causes sympathetic stimulation (i.e. **pressor response**) which;
 - Increases HR, ABP, ICP and IOP which in turn increases bleeding.
 - Induce bronchospasm in asthmatic patient.
 - Wound dehiscence.

- **To decrease the pressor response of extubation**, the same pretreatment is done as with intubation (see later).

b- Deep (Smooth) Extubation:

- It is done while the patient is **deeply anesthetized** by increasing the depth of anesthesia or **giving opioids or 10-20 mg propofol**. This is accompanied by measures to **decrease the pressor response of intubation** (as above). Removal of the ETT is only done after fulfilling the criteria of extubation.
- Indications: Mainly **to avoid the pressor response of extubation** in patients who can not tolerate them e.g. asthmatic, hypertensive, ischemic patients, neurosurgeryetc. But deep extubation is contraindicated in patients with risk of aspiration or expected difficult control of airway. Therefore, if both awake and deep extubation indications are present, **awake extubation indications have the priority**.

4- E.T.T. is withdrawn in a single smooth motion along its curve axis as careless withdrawal in straight line may damage laryngeal structure.

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- Extubation is preferred during inspiration when larynx is dilated, some anesthetists generate a +ve pressure in the trachea during withdrawal by squeezing the bag to propel secretions from trachea into the pharynx.

5- After extubation:

- Ventilate 100% O₂ by face mask ± airway to;
 - Avoid diffusion hypoxia of N₂O.
 - Provide a pulmonary reservoir of O₂ in case of breath-holding or coughing.
- Put the patient in lateral recovery position to;
 - Avoid risk of aspiration.
 - Detect possible bleeding e.g. after tonsillectomy (tonsillectomy position).
- Assess the patient as regards.
 - Ability to maintain airway.
 - Ability to cough.
 - Presence of secretions.

Difficult (Special) Extubation:**1- Tracheomalacia:**

- If it is suspected, **direct visualization** of airway patency is suggested. The **fiber-optic bronchoscope** can be used to assess for airway collapse and vocal cord movement as ETT and bronchoscope together are slowly pulled back. If tracheal collapse is noted, the ETT and bronchoscope should be immediately readvanced.

2- Laryngeal Edema (e.g. due to airway trauma):

- It can be assessed by;
 - Inspection as if there is external neck edema, venous congestion, duskiness of the head and neck, edematous tongue that extends beyond the incisors, and conjunctival and lid edema.
 - Air leak around the cuff.
 - Bronchoscope.
 - Airway trauma history.
- **Extubation trial is done** as the following;
 - At first, topical anesthesia to the airway before examination is applied to limit the stimulation that may result from examination, extubation, and possible re-intubation of the airway.
 - A ventilating tube exchanger or fiberoptic bronchoscope shaft may be placed via the ETT because when the ETT is removed, it becomes ready for immediate replacement.
 - The airway is observed for as long as one hour after extubation.
 - Auscultation of the larynx must be performed frequently searching for stridor.
 - Continuous pulse oximetry.

3- Hemophilic Patient:

- **Gentle oral suctioning under direct vision** is appropriate to remove all secretions because suctioning of the oropharynx of hemophilic patients can trap mucosa in the suction catheter and result in the formation of an oral hematoma.

4- Accidental Extubation:

- During surgery especially in abnormal positions e.g. prone, sitting position.

5- Extubation of obstructed sleep apnea patients:

.....see Anesthesia with nutritional diseases.

6- Indications of Awake and Deep Extubation: see before.

7- Complications of Extubation: see later.

Complications of Laryngoscopy and Intubation

I. Errors of E.T.T. Positioning:

A. Esophageal intubation:

- Effect: No O₂ is delivered to the patient's lung resulting in severe hypoxia that may cause death.

So, if you are in doubt regarding the position of E.T.T. or unexplained hypoxia occurred after intubation, removal of the E.T.T. and ventilation by mask may be life - saving.

- Detected by:

a. Reliable signs:

1. **Capnography** for consistent rise and fall of end tidal CO₂ with normal waveform is the most reliable method.

2. **Direct visualization** of the tip of the E.T.T. passing via the vocal cords.

3. **Fiberoptic bronchoscopy** by seeing tracheal rings and carina via E.T.T.

4. **Wee esophageal detector** to detect the esophagus.

5. Disposable **chemical indicators** to detect expired CO₂.

6. **Trans-tracheal illumination** by special light stylet (stilette) via the tube.

b. Unreliable signs:

1. Bilateral 4 quadrant **auscultation** of breath sounds with absence of gastric gurgling.

2. **Chest X-ray** to see the position of the tube.

3. Absence of cyanosis (hypoxia) or high pulse **oximeter** reading; it is unreliable, because if the patient is well preoxygenated, cyanosis (hypoxia) can be delayed up to 5 min.

4. **Expiratory condensation** of P.V.C. tubes.

5. **Chest or abdominal movement** with ventilation.

6. Refilling of anesthetic **reservoir bag**.

B. Endobronchial intubation: (especially right bronchus because it forms a smaller acute angle with the trachea).

- Effect: Large shunt occurs (ventilation/perfusion mismatching) causing hypoxia and decreased uptake of volatile agents. This leads to postoperative pulmonary collapse of the contralateral lung which later on acts as a nidus for infection (no change of PaCO₂ as long as the same minute ventilation is maintained. EtCO₂ changes little).

So, some anesthesiologists cut the tube to an appropriate length before intubation.

- Detected by:

1. **Unilateral breath sounds**, so auscultation should be done after securing the tube and after changing of patient position.

(neck extension or lateral rotation withdraws E.T.T. away from the carina while neck flexion pushes E.T.T. toward the carina).

2. **Unexpected hypoxia** with pulse oximetry. It is unreliable if the patient inspired high O₂ concentration.

3. Inability to palpate the tube cuff in the sternal notch during cuff inflation by pressing on pilot balloon.

4. Poor breathing bag compliance i.e. high peak inspiratory pressure.

5. **bronchospasm**.

C. Position of cuff in larynx: (above cricoid cartilage)

- It causes laryngeal trauma which leads to postoperative hoarseness of voice.

- Detected by;

1. Palpating the cuff over the thyroid cartilage.

2. Neck radiology.

AIRWAY MANAGEMENT**II. Airway Trauma:**

1. **Tooth damage:** is the most common cause of malpractice claims against anesthesiologists.
2. **Dislocated mandible:** during laryngoscopy.
3. **Lip and tongue ulcerations.**
4. **Sore throat**, in 80% patients.
 - Causes: Trauma by
 - Laryngoscope blade, airways, or nasogastric tubes to the pharynx or tonsillar fauces
 - E.T.T. especially red rubber and poorly secured as they cause more frictional trauma to the larynx.
 - Application of lubricants to E.T.T. can decrease (not prevent) the incidence of sore throat (no difference in incidence by use plain or local anesthetics jellies), but application of topical local anesthetics does not decrease the incidence of sore throat.
5. **Pressure injury on trachea:**
 - It causes **ulceration** which results in **circumferential fibrosis**. This causes **tracheal stenosis** (a late complication). Therefore, dry cough, inability to clear secretions and lastly attacks of pneumonia usually occur.
 - The cause of this injury is tissue ischemia produced by prolonged intubation as the pressure of E.T.T's cuff exceeds the capillary arteriolar blood pressure (about 30 mm Hg). It is found that minimal cuff inflation just to create a seal during routine +ve pressure ventilation (which is at least 20 mmHg) can decrease tracheal blood flow by 75% at cuff contact sites. So, further cuff inflation or N₂O diffusion or induced hypotension can totally eliminate mucosal blood flow.
6. **Edema of glottis or trachea** especially in children at cricoid cartilage causes post-intubation croup (see pediatric anesthesia).
7. Post-intubation **granuloma of vocal cords:**
 - It is very rare, occurring in the posterior 1/3 of vocal cords.
8. **Vocal cord paralysis:**
 - It is very rare, occurring especially with difficult intubations, obesity or long duration of intubation due to cuff pressure or trauma to recurrent laryngeal nerve. This causes hoarseness and increases the risk of aspiration.

Q: What are the causes of hoarseness after intubation?

III. Physiologic Responses to Airway Instrumentation:**1- Sympathetic stimulation →**

a- Hypertension (about 20-25 mmHg increase), tachycardia and arrhythmias.

b- Increased ICP and IOP:

- Avoided or decreased by;
 1. Deepening anesthesia with **potent volatile agents** for 10-15 minutes (sympathetic response is blocked when a concentration equivalent to 1.5 MAC is reached).
 2. **Opioids:** i.v. bolus as;
 - Fentanyl 2.5-8 µg/kg 4-5 min before laryngoscopy.
 3. **Lidocaine:** can be taken by many routes;
 - I.v. 1.5 mg/kg 2 min before laryngoscopy.
 - Intra-tracheally 2 mL 2% immediately before intubation.
 - Topical spray.
 - Intra-cuff filling (it is suitable for avoiding the pressor response of extubation).
 - Airway block.
 - Jelly.

4. **β - blocker:** i.v. bolus as
- Esmolol 0.3 - 1.5 mg/kg.
 - Propranolol 1 - 5 mg.

5. **Hypotensive agents:** i.v. bolus as
- Na nitroprusside 1-2 μ g/kg .
 - Nitroglycerine.

6. **Ca^{++} channel blockers:** i.v. as
- Verapamil 0.1 mg/kg 2 min before laryngoscopy.
 - Diltiazem 0.1-0.2 mg/kg 2 min before laryngoscopy.

7. Premedication with **clonidine** 0.2-0.3 mg.

8. Decrease **laryngoscopic time** ≤ 15 sec.

N.B.; • All these doses are used when a single agent is used. If a combination of agents are used so, decrease the doses otherwise severe hypotension occurs.
 • All these methods can be used to decrease the pressor response of extubation if they are given before extubation.

2- **Laryngospasm:**

- **It is:** a forceful, involuntary spasm of laryngeal muscles results in crowing inspiratory noise.

- **Cause:** stimulation of the superior laryngeal nerve.

- **Common in:** • Patients with history of smoking, asthma, bronchitis, or COPD.
 • With desflurane and isoflurane.

- **Triggering stimuli:**

- At induction; airway, laryngoscope, or E.T.T.
- During light anesthesia; extubation, surgical incision, anal stretch, cervical dilatation, or testicular surgeries.
- At recovery; pharyngeal secretions or vomitus.

- **Time of occurrence:**

It is usually, **immediate post-extubation**, but it may occur in the recovery room as the patient wakes up and chokes on pharyngeal secretions especially in pediatrics.

- **Avoided by:**

1. Extubation at awake (i.e. eye opening) or deeply anesthetized (i.e. spontaneous breathing, but no cough).
2. Clearance of pharyngeal secretions.
3. Recovery in lateral position so, oral secretions pool and drain away from the cords.

- **Treatment:**

1. **Gentle +ve pressure ventilation by bag and mask with 100 % O_2** with application of digital pressure at the **laryngeal notch**
2. I.v. **lidocaine** 1-1.5 mg/kg.
3. If it persists, **suxamethonium** 0.25 mg/kg to paralyze laryngeal muscles and allow controlled ventilation.
4. If it persists (hypoxia and bradycardia may occur) so, give **atropine + reintubate + 100% O_2 .**

N.B.; Doxapram is effective for laryngeal spasm after extubation.

N.B.; **Application of digital pressure at the laryngeal notch** (figure 4-23):

- It is a very helpful and simple method.

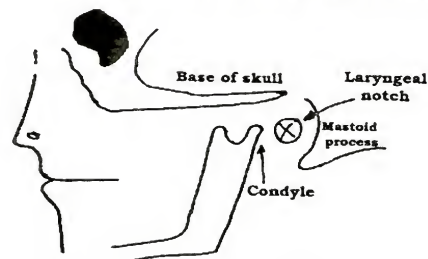


Figure 4-23; Laryngeal notch

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- Site of application:

This notch is located behind the lobule of the pinna of each ear. It is bounded anteriorly by the ascending ramus of the mandible adjacent to the condyle, posteriorly by the mastoid process of the temporal bone and cephalad by the base of the skull.

- Technique:

The therapist presses very firmly inwardly toward the base of the skull on each side using either index or middle fingers while at the same time lifting the mandible at a right angle to the plane of the body (i.e. forward displacement of the mandible or jaw thrust).

- Effects:

If it is properly performed, it will convert laryngospasm within one or two breaths to laryngeal stridor, and in another breath or two to unobstructed respirations. The technique works equally well in infants, children, and adults. Beside this, the technique prevents the tongue from falling back against the posterior pharyngeal wall (if with jaw thrust).

- Mechanism of action:

It is unknown, but it may be due to;

- Preventing airway obstruction from the tongue.
- Very painful stimulus that is elicited causing stimulation of several nerves including the facial nerves and the glosso-pharyngeal nerve (by pressing on the parotid gland) and vagus and perhaps sympathetic nerves.

3- Bronchospasm:

- It occurs after intubation especially in;

- Asthmatic patients.
- Endobronchial intubation \pm carinal stimulation.
- Over inflated tube's cuff.
- Tube obstruction.

IV. Endotracheal Tube Malfunction:

1. Risk of ignition of P.V.C. tubes in an O_2 / N_2O enriched environment.
2. E.T.T. obstruction by kinking, foreign body, biting of patient, aspirations or thick pulmonary secretions or cuff herniation (figure 4-24).
3. Cuff perforation.

N.B.; Complications following extubation:

- 1- Airway trauma: as above.
- 2- Physiologic response: as above.

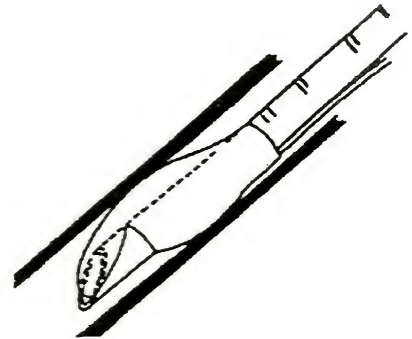


Figure 4-24; A herniation of the cuff that may occlude the distal end of the tube.

Difficult Airway and Intubation

Incidence: depending on experience;

1-3 % of anesthetized patients are **difficult intubation**.

0.05-0.2% of anesthetized patients have **failed intubation**

0.01 % of anesthetized patients are in the **cannot intubate, cannot ventilate** scenario.

Causes of Difficult Intubation:

I. Anesthetists: The most important cause.

due to 1. **Inadequate** preoperative assessment of patient.

2. **Inadequate equipment** preparation.

3. Inexperience, poor technique.

4. Absence of trained assistant.

II. Patients: (= Preoperative Assessment)

A. Congenital:









- As Down's syndrome, Pierre robin syndrome, Marfan's syndrome, cystic hygroma, achondroplasia, encephalocele or hydrocephalus.

B. Anatomical features: (from above downward examination)

1. Teeth: • Protruding incisors (buck teeth); as the blade enters the mouth in cephalad direction.
 - Intercisor distance; if < 3 cm so, the phalange of the blade can be easily inserted between teeth.
2. Palate: • Long high arched palate.
3. Tongue: • Large tongue.
4. Jaw and mandible: • Receding of the lower Jaw (retrognathia)
 - Hypoplastic mandible (micrognathia).
 - Obtused mandibular angle.
 - Poor mandibular mobility.
 - Increased anterior depth of the mandible.
 - Increased posterior depth of the mandible (by x-ray) resulting in decreased Jaw opening.
5. Neck: • Short muscular neck.
6. Distances:
 - Decreased distance between spine of C_1 and occiput (atlanto-occipital) causes limitation of neck extension (by x-ray).
 - Distance between tip of chin and thyroid cartilage prominence (thyro-mental distance) < 6.5 cm (Patil examination).
 - Distance between tip of chin and sternum < 12.5 cm with fully extended head and closed mouth.

7. Mallampati classification.

By voluntary tongue protrusion with maximal mouth opening while the patient is sitting.

Grade	I	II	III	IV
Appearance on mouth opening				
Appearance on laryngoscopy by Cormack and Lehane				
Uvula	All the uvula is visible.	The tip of the uvula is not visible	Only the base of uvula is visible	All the uvula is not visible.
Larynx	Most of glottis is visible.	Only the posterior part of glottis is visible (arytenoids)	No part of glottis is visible, but only epiglottis is visible.	Not even the epiglottis is visible, only the soft palate is visible.
Degree of difficulty	No difficulty, easy intubation.	Slight difficulty, need pressure on the neck.	Severe difficulty, need stylet or bougie.	Very severe difficulty, usually with obvious pathology. It needs more complex methods.

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C. Acquired:

1. **Decreased jaw opening** causing difficult laryngoscopy.

- Muscle: • Reflex spasm of masseter and medial pterygoid (trismus) by infection/ abscess, fracture or tetanus.
- Temporo-mandibular joint: • Fibrosis (post-infection, radiotherapy, trauma).
• Rheumatoid arthritis or ankylosing spondylitis.
- Bone: • Fracture mandible or maxilla.
• Jaw wiring.
- Soft tissue: • Tumors, edema.

2. **Decreased neck movement or presence of neck instability:**

- Rheumatoid arthritis • Osteomyelitis • Ankylosing spondylitis.
- Cervical spine injury as fracture, fusion, instability (need recent spine x-ray).

3. **Airway:**

- Airway edema: due to abscess, infection, trauma, angioedema or burns.
- Airway compression: due to goiter or surgical hemorrhage.
- Airway scarring : due to radiotherapy, infection or burns.
- Airway mass: due to tumors, polyps or foreign body.
- Airway collapse: due to Laryngo-tracheomalacia.

4. **Others:**

- **Morbid obesity.**
- **Pregnancy.**
- **Acromegaly**

N.B.; Previous anesthetic records should be always consulted, but a past record of normal tracheal intubation is no guarantee for future anesthesia because acquired causes may occur leading to a change in the airway.

Preoperative (Pre-intubation) Preparation

1. **Psychologic** support to the patient: It makes the patient more co-operable during awake intubation. Patients' consent may be taken.
2. Presence of • **an experienced anesthesiologist.**
• **a trained assistant.**
3. Special "**difficult intubation**" trolley with a range of equipment such as different tube sizes, bougies, stylets, laryngoscopes etc.
4. Presence of functioning **suction** unit.
5. Full **preoxygenation**.
6. **Premedication.**
 - **Anti-sialagogue:** - Especially before awake fiberoptic endoscopy (to maximize the effect of topical LAs) and before inhalational induction.
- By glycopyrrolate, preferred (over atropine) as it does not cross B.B.B. so, it has no effect on consciousness.
 - **Sedatives:** small doses or omitted to avoid decreased level of consciousness.

Intubation Techniques:

- There are many methods of trans-laryngeal intubation. The choice between them depends on - Experience of the anesthetist.
 - Availability of the technique.
 - Patient condition e.g. no nasal intubation in face trauma.
- These techniques include:
 - Awake or asleep.
 - Oral or nasal.

- Blind, laryngoscope, or fiberoptic.

These give about 12 different methods e.g. awake nasal fiberoptic intubation. +
 13. Laryngeal mask (used as a stylet through it, a smaller tube or bronchoscope can pass).
 14. Combi-tube.

15. Tracheostomy or cricothyrotomy (surgical airway).

+ Other method of ventilation;

As 16. Mask ventilation.

17. Nasopharyngeal airway or cuffed oropharyngeal airway (COPA).

18. Jet ventilation.

Optimal/Best Laryngoscopic Intubation Attempt:

Failure of one laryngoscopic intubation should force the anesthesiologist to perform the 2nd intubation in optimum conditions:

1. Reasonably **experienced** anesthesiologist (the experience of using the laryngoscope is usually reached maximal after 2-3 years of experience).
2. No significant resistive **muscle tone** (the best is suxamethonium as rapid onset, potent and short duration).
3. **Sniffing position**.
4. **Optimal external laryngeal manipulation (OELM)** by **trained assistant**, instructed by the anesthesiologist. This may improve laryngoscopic grade one degree.
5. Change the length of the **blade** of the laryngoscope to a larger **size** (either Macintosh or Miller).
6. Change the **type of the blade** (sometime);
 as - Macintosh blade is preferred in patients with little upper airway room to pass E.T.T. e.g. small narrow mouth, palate or oropharynx.
 - Miller blade is preferred in patients with small mandibular space (i.e. anterior larynx), large incisors long floppy epiglottis.

Optimal/Best Mask Ventilation Attempts:

Before using the emergency pathway of the algorithm (i.e. inadequate mask ventilation), the optimal mask ventilation should be done:

1. 2-person efforts either;
 - a- 2-hand efforts, if the assistant can only squeeze the reservoir bag.
 - b- 3-hand efforts, if the assistant can do Jaw thrust (better ventilation) (figure 4-25).
2. Using large oro- &/or nasopharyngeal airway.

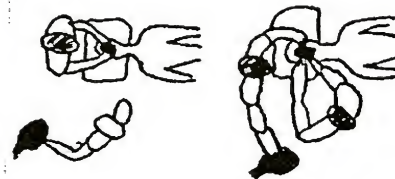


Figure 4-25; 2- & 3-hand effort mask ventilation

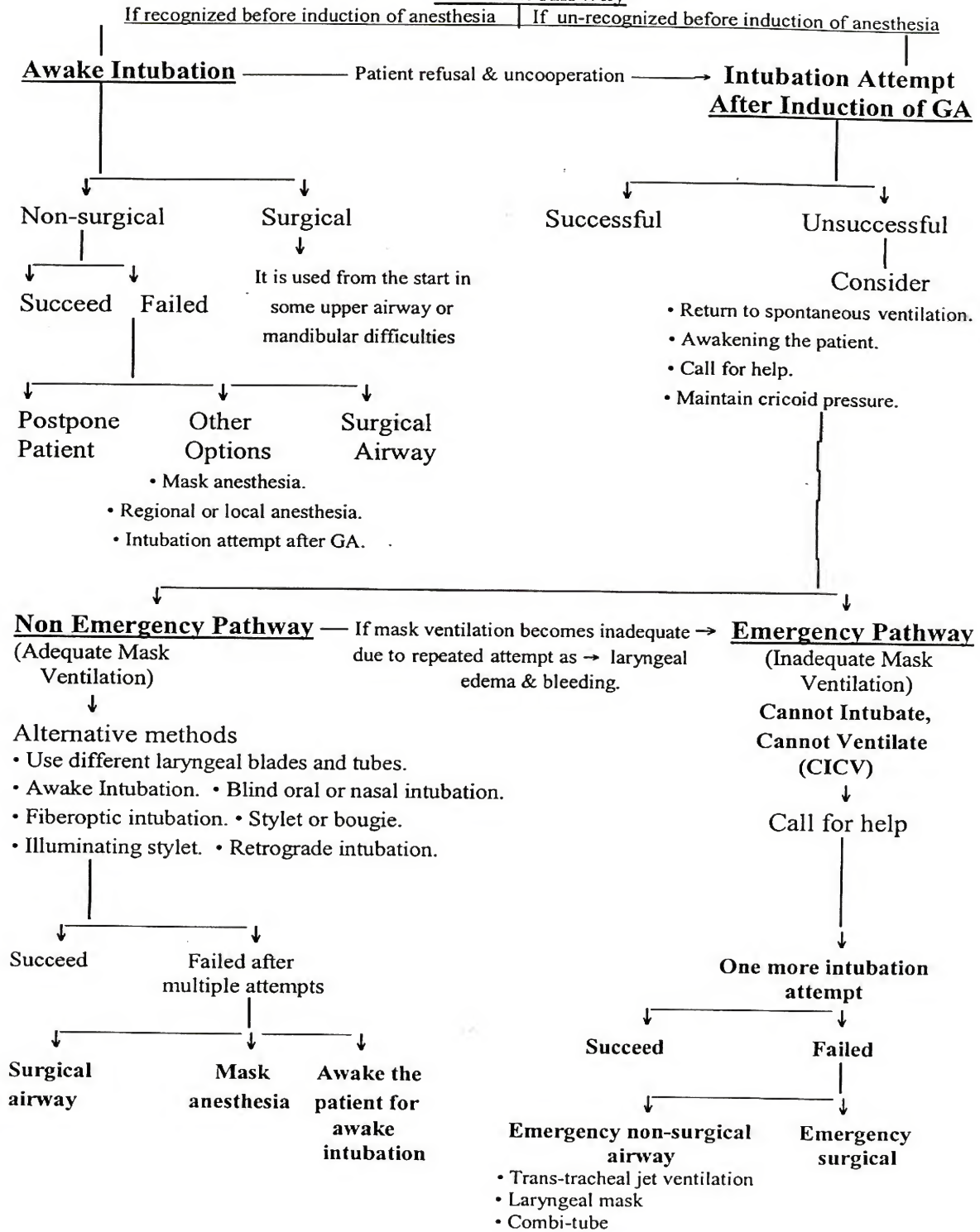
- Obviously, prediction of difficult airway or intubation is much safer than facing a problem of failed intubation drill. When facing this problem, early decision to use the algorithm of difficult airway and intubation is much safer.

- Before using the algorithm, consider the relative merits and feasibility of basic management choices between:

- Non surgical or surgical techniques for initial approach to intubation.
- Awake or asleep intubation.
- Preservation of spontaneous ventilation or the need of muscle relaxation.

Difficult Airway Algorithm (Protocol)

By American Society of Anesthesiologists (ASA)

Difficult Airway

Awake Intubation

- It can be done by either:

1. Direct laryngoscopy.
2. Blind intubation (oral or nasal).
3. Fiberoptic intubation.

The choice depends on the anesthesiologist's training and experience.

- Patient preparation is very important (as before).
- Analgnesia of the airway is done as the following;

A. For Nasal Intubation:

1. Anesthesia of The Nasal Passages: by;

- 40% cocaine spray (max. 2.5mL/70 kg)
- or 4% lidocaine spray + 0.25% phenylephrine nasal drops, both cause vasoconstriction of mucous membrane vessels leading to shrinkage of the mucous membrane (cotton tipped applicators can be used instead of the spray).
- Then, a well lubricated soft nasopharyngeal airway (size 6 or 7) is then gently inserted into the nasopharynx and left in situ for 3-5 min. then removed to apply the lubricated tube or fiberoptic shafts.

2. Anesthesia of The Oropharynx And Supra-glottic area: by;

- Lidocaine spray which is introduced through the nasopharyngeal airway then proceed to step C and D.

B. For Oral Intubation:

Anesthesia of The Posterior 1/3 of The Tongue And Oropharynx: by;

- Bilateral injection of 2 mL of local anesthetics into the **base of the anterior tonsillar pillars (platoglossal arch)**, while the tongue is laterally retracted by tongue blade.

Injection is done by 25-guage spinal needle (it blocks the lingual and some pharyngeal branches of the glosso-pharyngeal nerve) (figure 4-26).

Or • By simply anesthetizing oropharynx by progressive lidocaine spray until the patient can tolerate deep insertion of laryngoscope.

Then proceed to step C and D.

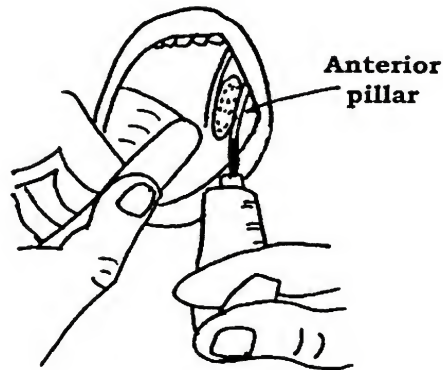


Figure 4-26; Anesthesia of the posterior 1/3 of the tongue and oropharynx.

C. Bilateral Superior Laryngeal Nerve Block:

(For oral & nasal routes) (figure 4-27)

- It is used to anesthetize **airway above the glottis**.
- The hyoid bone is located, and 3 mL of 2 % lidocaine is infiltrated 1 cm below each greater cornu where the internal branch of the superior laryngeal nerves penetrates the thyrohyoid membrane.

D. A Trans-tracheal Block: (For oral & nasal routes)

- After extending the neck, locate the cricothyroid membrane and after confirmation of an intra-tracheal position by aspiration of air using a 21-G needle in the midline, 4 mL of 4% lidocaine is injected inside the tracheal lumen at the end of expiration. This causes a deep inhalation and cough immediately after injection which distribute the lidocaine through out the trachea.
- Both C and D depress protective cough reflexes and swallowing reflex which increases the risk of aspiration although the patient is fully awake.

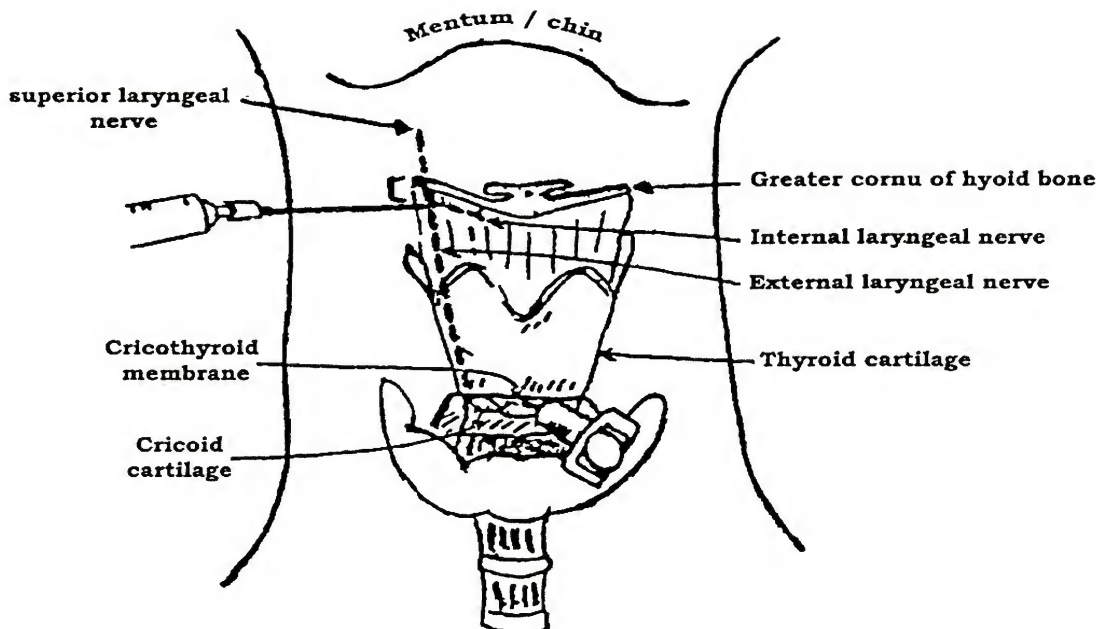
AIRWAY MANAGEMENT

Figure 4-27; Bilateral superior laryngeal nerve block and trans-tracheal block

- C alone causes transient obstruction of the pharynx from loss of reflex regulation of the airway caliber at the level of the glottis.

So, alternative techniques should be done in patients who are at risk of aspiration.

Instead of C and D do **"spray as you go technique"** by injection aliquots of lidocaine via the suction port of the fiberoptic laryngoscope as it is advanced.

N.B.; Do not exceed the calculated maximum safe dose of local anesthetics.

Blind Nasal Intubation

- Lubricate E.T.T. with lidocaine jelly and deform it for a few minutes to exaggerate its curvature.
- The patient's head should be in the sniffing position.
- Introduce the tube gently via the nostril perpendicularly to the face.
- Air movement through the tube should be continually felt, heard or monitored by capnography.
- The tube is advanced during inspiration. If the patient's respiration continues, but no air flow is detected via the tube so, the tip has passed the glottis and now is in the esophagus. Therefore, withdraw the tube and advance it again.
- Breath-holding and coughing indicate close proximity to the larynx.
- If the tube does not easily enter the trachea, several maneuvers are done:
 1. A stylet that has been bent to resemble a hockey stick.
 2. Extension of the head to move the tip of the tube anteriorly.
 3. Rotation of the head to move the tip of the tube laterally.
 4. Laryngeal or cricoid pressure.
 5. Inflation of the tube's cuff in the hypopharynx may guide the tip anteriorly.
 6. If the tube persistently slips into the esophagus, voluntary tongue protrusion will inhibit swallowing and may move the tongue and the tube anteriorly to the trachea.

Retrograde Intubation

As a wire or epidural catheter (via a touhy needle) is introduced through the cricothyroid membrane. It passes retrograde up to oropharynx then to the mouth or the nose. Then E.T.T is railroaded over the catheter into the trachea

Important Notes:

• In Patients With Glottic or Sub-glottic Obstruction of Airway:

Methods used are:

1. E.T.T
2. Trans-tracheal jet ventilation.
3. Surgical airways.

Both LMA & combi-tube are of no value
as both can not supply air to the trachea.

• Role of Regional Anesthesia in Difficult Airway Patient:

As there is a risk of failure or complication of regional anesthesia which needs to control airway, therefore **do not depend only on the regional anesthesia in difficult airway** because it does not solve the problem so, you must have the ability to either;

- Stop the surgery, if it is very small and superficial.
- Change to a new plan of airway control in cases of failure or complication.

• Induction of General Anesthesia in Difficult Airway Patients:

According to the degree of expected difficulty and airway obstruction.

1. Cases with **little expected difficulty and no airway obstruction:**

Use - **I.v. induction** (especially with patients **at risk of aspiration**).

- **Inhalational induction** (especially with patients **not at risk of aspiration**).

2. Cases with **severe expected difficulty and little airway obstruction:**

Use **inhalational induction only** (i.v. induction is contraindicated) because during inhalational induction, airway obstruction may increase causing limitation of the uptake of inhalational agent. This causes awakening of the patient.

3. Cases with **severe airway obstruction:**

Awake intubation is used.

4. **The most severe cases of airway obstruction:**

Surgical access i.e. tracheostomy under local anesthesia.

CHAPTER 5

MONITORING DURING ANESTHESIA

Recommendations of Association of Anesthetists of Great Britain & Ireland (1994):

- 1- An anesthesiologist must be present throughout the conduct of general anesthesia, regional anesthesia and monitored anesthesia care (**standard I**).
- 2- Monitoring should be started before induction and continued until patient's recovery and during patient transfer (If required).
- 3- Monitoring is done for general, local or regional anesthesia whatever the length of anesthesia.
- 4- Monitoring equipment must be checked by anesthesiologists before usage.
- 5- Essential monitoring for all anesthetized cases include (**standard II**);
 1. Clinical observation: the **most important**.
 2. Peripheral pulse.
 3. ECG.
 4. Non-invasive BP.
 5. Pulse oximetry.
 6. End-tidal CO₂
- + - Neuromuscular monitoring, if muscle relaxant is used.
- Body temperature, if the patient is at risk of hypothermia.
- O₂ analyzer and alarms, if anesthetic machine is used.
- More sophisticated monitoring, according to patient's condition.

N.B.; **Monitored Anesthesia Care (MAC):**

- It refers to monitoring the patient by an anesthesiologist during a procedure performed with intravenous sedation or local anesthesia administered by the surgeon.
- It was previously referred to as local standby anesthesia.

Cardiovascular System Monitors

They include:

- I- Peripheral pulse.
- II- Tissue perfusion.
- III- ECG.
- IV- Arterial blood pressure: Non-invasive & invasive.
- V- Central venous catheterization.
- VI- Pulmonary artery catheterization.
- VII- Cardiac output (CO) measurement.
- VIII- Trans-esophageal echocardiography.
- IX- Measurement of blood loss.

I- Peripheral Pulse:

By regular palpation.

II- Tissue Perfusion:

It is the best clinical assessment for cardiac function and managing of shock. It should be employed before more invasive techniques are done.

1-Peripheral Perfusion (By Skin):**a- Capillary Refill:**

- Rapid return of blood to nail bed after slight pressure indicates good peripheral perfusion.

b- Observation of Patient's Extremities (Especially in Children):

- Warm, dry, pink skin indicates adequate peripheral perfusion.

- Cold, white skin indicates inadequate peripheral perfusion.

c- The Core-Peripheral Temperature Gradient:

- One temperature probe is placed centrally e.g. in nasopharynx and the other temperature probe is placed peripherally e.g. one great toe.

- Normally, the difference between them = $< 5^{\circ}\text{C}$

But • Decreased temperature gradient occurs in peripheral VD or high CO.
• Increased temperature gradient occurs in peripheral VC or Low CO.

2- Cerebral Perfusion:

- E.g. by mental status.

3- Gastric Intra-mucosal pH (pHi):

- The adequacy of gut mucosal perfusion is assessed indirectly by its pH.
If pHi is < 7.2 , it indicates mucosal ischemia.....see later.

4-Acid-Base Status and Serum Lactate:

- As tissue hypoperfusion causes;

• Decreased PaO_2 .

• Decreased pH (acidosis).

• Increased s. lactate.

N.B.; Normal s. lactate is $< 2 \text{ mmol/L}$

- In distressed patients, it is $2-4 \text{ mmol/L}$.

- In ischemic tissues, it is $> 4 \text{ mmol/L}$.

5- Mixed Venous O_2 Saturation ($\text{S}\bar{\text{v}}\text{O}_2$) or Tension ($\text{P}\bar{\text{v}}\text{O}_2$):

- Normally; - $\text{S}\bar{\text{v}}\text{O}_2$ is 75 %.

- $\text{P}\bar{\text{v}}\text{O}_2$ is 40 mm Hg.

- If it is $< 28 \text{ mm Hg}$, it indicates poor tissue perfusion.

- It should be interpreted with care as presence of arterio-venous shunt may elevate the values despite of tissue hypoxia.

6- Urine Output (UOP) for Renal Perfusion:

- It indicates renal perfusion which reflects;

• Renal function. • C.V.S. status.

• Fluid volume status.

- Normal UOP = $0.5 - 1 \text{ ml/Kg/hr}$.

- Oliguria occurs with UOP $< 0.5 \text{ ml/Kg/hr}$.

+ 7- Peripheral Pulse.**8- Arterial O_2 Saturation.****9- Arterial BP.****10- CO Measurement.**

III- Electrocardiography (ECG):

- It indicates only electrical potentials generated by muscle cells (but does not indicate cardiac output as patients with very low C.O. may have good ECG tracing).

Uses: It is used for the detection of;

1- **Arrhythmias:** by lead II (it is the most sensitive for arrhythmia).

2- **Myocardial ischemia:**

Recently, new automated ST segment analysis is available.

3- **Conduction abnormalities.**

4- **Pacemaker malfunctions.**

Choice of lead:

• **Three-lead system:**

Bipolar lead system	Electrode placement	Selected lead on monitor	Simulated ECG lead	Advantages (best for...)
II	- RA at right clavicle - LA at left 10 th rib (mid-clavicular line) - LL, ground	II	II	- Arrhythmia - Inferior wall ischemia
CM5 (modified lead V5)	- RA over manubrium sterni - LA at apex (V5) - LL, ground	II	V5	- Anterior wall ischemia (precordial ischemia)
CB 5 (central back)	- RA over right scapula - LA at apex (V5) - LL, ground	I	V5	- Anterior wall ischemia (precordial ischemia). It is usually for thoracic surgery.

RA = right arm lead i.e. -ve (red),

LA = left arm lead i.e. +ve (yellow),

LL = lower limb lead i.e. indifferent (black).

• **True lead V5:** It is done by 5-lead ECG.

It is the best for detection of **anterior and lateral wall ischemia** (i.e. left ventricle).

• **Esophageal lead:** It is done by a special lead inserted inside the esophagus.

It is the best for detection of **posterior wall infarction and dysrhythmia** (it is better than lead II, but it is not commonly used in the OR). So, if only a single-channel monitor is available, the choice between leads depends on the prior history of site of infarction. Because V5 is the most common site of ischemia in most patients (80% of ischemia), therefore, CM5-Lead II configuration is displayed (figure 5-1).

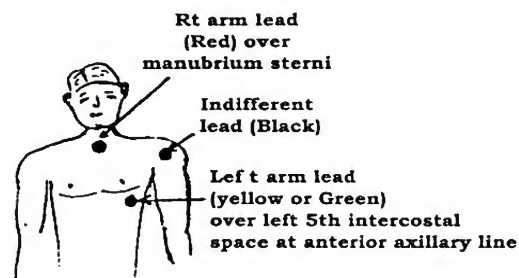


Figure 5-1; CM5-Lead II configuration

N.B.; ECG is one of the following;

- 1- Three- lead ECG monitor.
- 2- Five- lead ECG monitor.
- 3- Twelve- lead ECG trace.
- 4- Holter or ambulatory ECG trace.
- 5- Exercise ECG trace.

IV- Arterial Blood Pressure (ABP):

- ABP reflects CO because $\text{mean ABP} = \text{CO} \times \text{Systemic peripheral resistance}$

So, ABP reflects organ and tissue perfusions.

- Mean ABP (MABP)

= Diastolic BP + $\frac{1}{3}$ Pulse pressure.

N.B.; Pulse pressure = Systolic BP - Diastolic BP.

N.B.; Pressure units:

7.6 mmHg (torr) = 1 KPa = 10 cm H₂O

A- Non-invasive BP Monitoring (NIBP):

Indications:

For all patients to be anesthetized, mostly every 5 minutes.

There are no contraindications except avoiding cuff application in limbs with dialysis shunt or simply with iv. lines.

Techniques:

1-Palpation Method.

2- Auscultation Method:

Principles:

- On cuff deflation, **Korotkoff sounds** occur due to blood flow in stenosed vessels causing turbulent flow which produces the sound.

- It consists of (figure 5-2):

- Phase I: 1st appearance of the sound i.e. onset of blood flow = systolic BP.
- Phase II: Sound is slightly muffled.
- Phase III: Increase in the sound volume.
- Phase IV: Abrupt fall in the sound, muffling again. It is sometimes considered diastolic BP. (e.g. hyperdynamic circulation as pregnancy, aortic incompetence, thyrotoxicosis).
- Phase V: Final loss of the sound. It is usually considered diastolic BP.



Figure 5-2; Korotkoff sounds

Technique: The following notes are important.

- Manometers: either;
 - Aneroid gauge; should be calibrated regularly.
 - Mercury column; should be used vertically.
- Stethoscope:
 - It should be placed over the course of the artery i.e. medially.
 - Diasyst, is a specially molded rubber stethoscope that is secured under the cuff.
- **Auscultatory gap:** It is the disappearance of Korotkoff sounds through part of the range from systolic to diastolic BP. It may cause inaccurate reading.

3- Doppler (U/S) Probe (Arteriosonde):

Principles:

- It is U/S emitter & receiver (with **piezo-electrical crystal**) that emits U/S waves (1-5 MHz) and receives these waves. It is placed over the brachial artery, with inflated cuff.
- On cuff's deflation;
 - At systolic BP, blood starts to pass in the vessels and the vessels walls begin to move apart producing a certain shift in U/S frequency which is detected. It causes a characteristic sound pitch.
 - At diastolic BP, no more movement is detected causing another characteristic sound pitch.

4- Oscillometry:

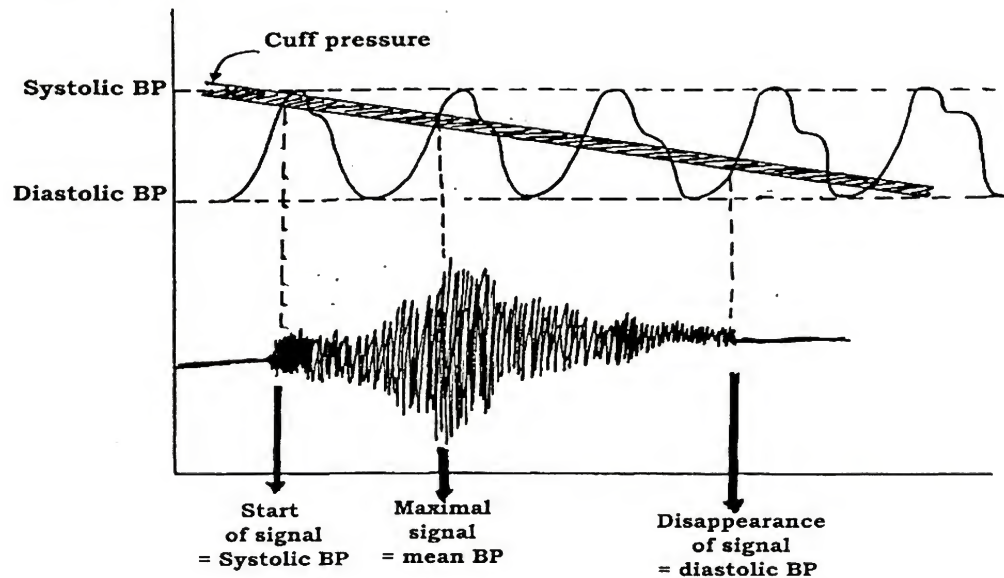


Figure 5-3; Oscillometry

Principles:

- As BP cuff is deflated from above, **oscillation** in the cuff pressure occurs (like the oscillations in mercury column or aneroid gauge needle) (figure 5-3).

- Onset of oscillation = Systolic BP.
- Maximum of oscillation = Mean BP.
- Offset of oscillation = Diastolic BP.

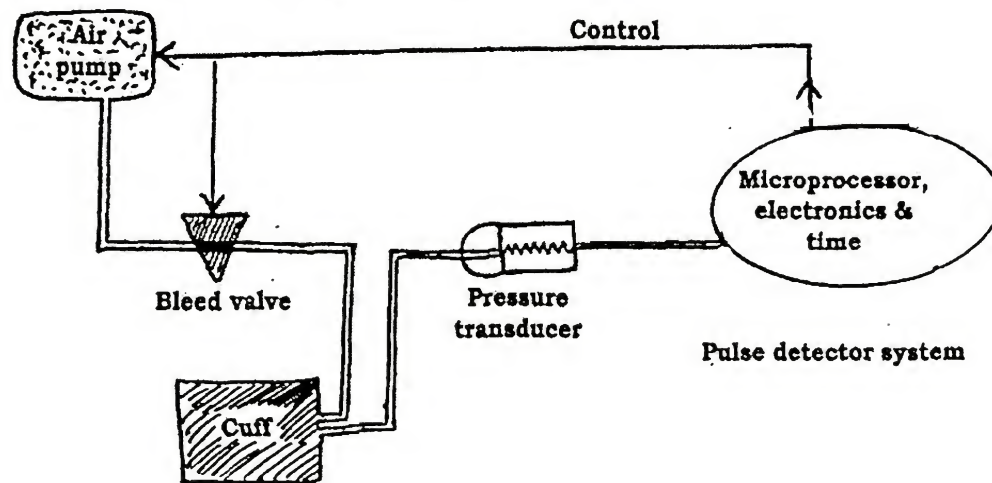


Figure 5-4; Automated Oscillometer

Automated Oscillometer consists of (figure 5-4):

- A microprocessor that controls the inflation and deflation sequence.
- An air pump that inflates the cuff.
- A bleed-valve that deflates the cuff at rate of 2 -3 mm Hg/sec.
- A pressure transducer that records the oscillating pressure signals which in turn interpreted by the microprocessor.
- 2 tubular connections are connected to the cuff.
 - One for inflation of the cuff.

- The other senses (detect) the pressure fluctuations and transmits them to the pressure transducer.

NB; Von Recklinghausen Oscillometer:

It is an old model.

Disadvantage:

- 1- It is **inaccurate** at - Low systolic BP < 60 mmHg e.g. shock or heart lung machine.
 - High systolic BP as it underestimates it.
 - Period of dysrhythmias.
- 2- It is **not suitable for rapid changes of BP** as one reading takes one minute. Even at this rapid rate, it may impede blood flow.
- 3- Complications of **repeated cuff inflations** as ulnar nerve injury, petechial hemorrhage, and extravasation of i.v. fluids.

B- Invasive BP Monitoring:

It is the **gold standard** for ABP measurement. It provides **continuous** beat to beat pressure measurement.

Indications:

- 1- Anticipation of wide intraoperative **BP swings**.
E.g.
 - Cardiothoracic surgery.
 - Surgery for pheochromocytoma.
 - Major organ transplantation as heart, lung, kidney or liver.
 - Major vascular surgery.
 - Neurosurgery.
- 2- **Elective hypotension.**
- 3- **End organ disease** requiring beat to beat BP regulations.
E.g.
 - Critically ill patients and shocked patients.
 - Inotropic therapy.
- 4- **Inability to record NIBP** e.g.
 - Very obese patients.
 - Very extensive burns.
- 5- Need of multiple **arterial blood gases analysis (ABG analysis).**

Contraindications:

- 1- **Arteries without** documented **collateral** blood flow.
- 2- **Limb** with suspicion of preexisting **vascular insufficiency** e.g. Raynaud's phenomenon.

Technique:

A- Selection of Artery for Cannulation:

- 1- **Radial artery:** common, in the non-dominant hand.

Ulnar collaterals should be tested by

- a- **Allen's test:** Originally, 1st described by Allen in 1929 to test collaterals in patient with thrombo-angitis obliterans.
 - It is not completely reliable and needs patient cooperation.
 - The patient exsanguinates the hand by making a fist. If the patient is under anesthesia so, a 3rd person can squeeze the hand.
 - While the operator occludes the radial and ulnar arteries with finger tip pressure, the patient relaxes the blanched hand.
 - When the pressure on the ulnar artery is released, flushing of the thumb occurs.
- If it occurs within 5 sec after pressure release, this indicates good collaterals.
If it occurs within 5-10 sec after pressure release, this indicates an equivocal test.
If it occurs after 10 sec after pressure released, this indicates insufficient collaterals.

- b- **Alternative methods**, without patient cooperation.
As blood flow distal to the radial artery occlusion can be detected by **palpation, doppler probe, plethysmography or pulse oximetry (modified Allen test).**
- 2- Other arteries as ulnar artery, brachial artery, dorsalis pedis artery, posterior tibial arteries and femoral artery.

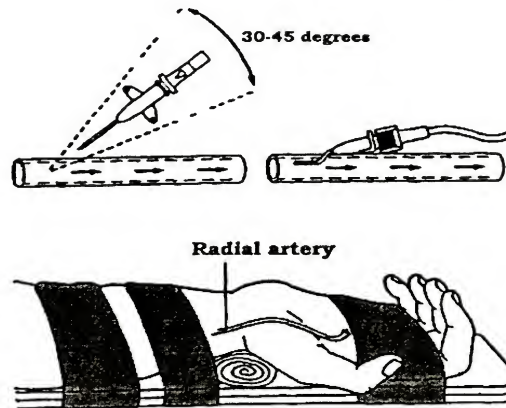
MONITORING DURING ANESTHESIA**B- Technique of Arterial Cannulation** (e.g. radial artery) (Figure 5-5)

Figure 5-5; Technique for arterial line placement

- Supination and extension of the wrist to provide optimal exposure of the radial artery.
- The pressure-tubing-transducer system should be nearby and already flushed with heparinized saline (0.5-1.0 unit of heparin per mL of saline).
- The radial pulse is palpated and the artery's course is determined by lightly pressing the tips of the index and middle fingers.
- After preparing the skin with iodophor and alcohol solution, 0.5 mL of lidocaine is infiltrated directly above the artery with a 25-27 gauge needle.
- A 20- or 22- gauge Teflon cannula-over-needle assembly penetrates the skin at a 45- degree angle and is directed toward the point of palpation.
- Upon blood flashback, the needle is lowered to a 30- degree angle and advanced another 2 mm to make certain that the tip of the catheter is well into the vessel lumen.
- The catheter (cannula) is advanced over the needle which is then withdrawn.
- Applying pressure with the middle and ring fingertips prevents blood spurting while the tubing is firmly connected.
- Waterproof tape or suture is used to keep the catheter in place to avoid fatal blood loss.
- The cannula is connected by a stopcock and saline filled high pressure tubing to a transducer which is a diaphragm (strain) gauge type causing stretching of wire or silicone crystals. This causes a change in its electrical resistance which affect Wheat stone bridge circuit. The voltage output is proportionate to the pressure applied to the diaphragm.

C- Transducer Zeroing:

- A stopcock is put at the level of the desired point of measurement.
 - **Systemic BP:** in supine patient at **mid-axillary** line.
 - **Cerebral BP:** in seated patient at the ear. (represent circle of Willis pressure).
- The stopcock is opened, the zero with switch on the monitor is activated.

N.B.; Change in patient's position e.g. lowering or raising the operation table.

Or - Re-zeroing at the new mid-axillary line.

Value of Arterial Cannulation:

1- It is more **accurate** than NIBP.

- For systolic BP, 5 mm Hg higher than NIBP.
- For diastolic BP, 8 mm Hg lower than NIBP.

2- Waveform:

- The shape of the arterial wave can indicate:
 - The **rate of the upstroke** indicates **contractility**.
 - The **rate of the down stroke** indicates **peripheral vascular resistance**.
 - **Exaggerated variations in size during respirations or with IPPV** indicate **hypovolemia (i.e. decreased preload)**.
 - **Area under the pressure curve** indicates **mean ABP**.

- Note:

- **Dicrotic notch** is due to intra-aortic vibrations.

- The **quality of the waveform** depends on the dynamic characteristics of the catheter-tubing-transducer system (figure 5-6).

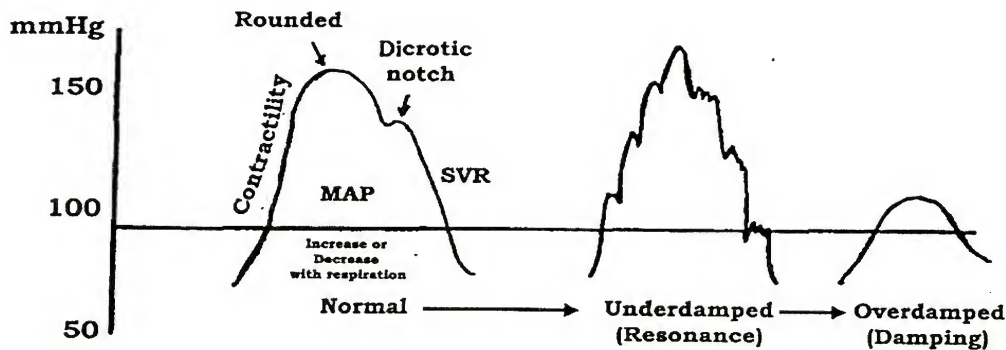


Figure 5-6; Arterial waveform

a- Hyper-resonance (Under-damped):

- Movement of the diaphragm of the pressure transducer converts BP changes into electrical signals. These movements are associated with very small movement of saline to & fro along the catheter with pressure changes (as a weight on the end of a spring).
- They will oscillate at a particular frequency called the **natural resonant frequency**.
- The arterial pulse natural resonant frequency is usually between 16-24 Hz (in other authors, it is < 40 Hz).

So, If the resonant frequency of this system falls within the frequency of arterial pulsation these oscillations make a sine wave which superimpose on BP waveform causing distortion of BP wave form.

- Most transducers have frequencies of several hundred Hz (usually > 200 Hz). The addition of tubing and stopcocks and air in the line decreases the frequency of the system.
- So, the natural resonant frequency of the system should exceed that of arterial pulse, this occurs by;

- 1- Decreasing tube or catheter length.
- 2- Increasing tube or catheter width.
- 3- Use a stiffer tube or catheter (i.e. lower compliance).
- 4- Eliminating unnecessary stopcocks.
- 5- Removal of air bubbles.

b- Damping (Over-damped):

I.e. the sharp changes occurring in BP are not transmitted to the system and so, are not displayed.

- Causes of damping:
 - Air bubbles / blood in the system.
 - Kinking of the cannula.
 - Arterial spasm.

Complications of Arterial Cannulation:

- 1- Hematoma.
- 2- Vasospasm.
- 3- Thrombosis.
- 4- Embolization of air bubbles or thrombi.
- 5- Skin necrosis overlying the catheter.
- 6- Nerve damage.
- 7- Infection.
- 8- Loss of digits.
- 9- Disconnection causing fatal blood loss.

MONITORING DURING ANESTHESIA**V -Central Venous Catheterization (CVP):****Indications:****1- Fluid management in:**

- Hypovolemia and shock.
- Surgery with expected large fluid shift e.g. splenectomy, open cardiac surgery.

2- Infusion of:

- Caustic drugs as chemotherapy drugs.
- Hyper-alimentation as total parenteral nutrition (TPN).
- Fluids or blood if large amounts are needed.

3- Aspiration of:

- Air embolism.

4- Insertion of:

- Trans-cutaneous (trans-venous) pacemaker.
- Pulmonary artery floatation catheter.

5- Venous access in:

- Patients with poor peripheral veins.
- Hemo-filtration & hemo-dialysis.
- Plasma-phoresis.

N.B.; For measurement of RA pressure or aspiration of air emboli; the tip of the cannula should be at the junction of SVC & RA assessed by chest X-ray.

Contraindications:

- 1- Renal cell tumor extension into the RA.
- 2- Fungating tricuspid valve vegetations.
- 3- At the cannula site e.g. internal jugular vein cannulation.
 - Patients receiving anticoagulants.
 - Ipsilateral previous carotid endarterectomy (due to risk of carotid artery puncture).

Value of CVP:**a- Normal Range:**

= 5-10 cm H₂O If mid-axillary line is used as a reference point in supine spontaneously breathing patient.

- It varies with;

1. Respiration: as during inspiration expansion of thoracic cavity occurs which increase the negativity of intra-thoracic pressure. This negative pressure is transmitted to the relatively thin walled RA and venae cavae causing a decrease of CVP. The reverse occurs during expiration causing an increase of CVP.

2. Controlled mechanical ventilation makes CVP 5 cm H₂O higher.

3. If manubrio-sternal junction is used as zero reference (which usually occurs), CVP is 5 cm H₂O lower.

- CVP gives information about;

- Intravascular blood volume.
- Venous return.
- RA pressure which reflects RV end diastolic volume which reflects RV function.

- CVP measurement is only of value if;

1- It is used in combination with other measures and clinical signs e.g. ABP, HR, UOP, and body temperature.

2- Comparing the trend of values and the response to intervention (more important than absolute values).

E.g. - CVP from +5 to +1 cm H₂O indicates large fluid loss although both are normal values.

- A young patient with an increased CVP if he receives i.v. fluid so,

If CVP is decreased so, it is hypovolemia and CVP was high due to severe sympathetic stimulation which causes venous VC.

If CVP is increased more so, it is heart failure and CVP was high due to decreased cardiac pump action.

B- Normal Shape:

CVP is related to RA pressure changes.

CVP waveform (figure 5-7):

	Due to	ECG related	P ^r ase (Time at which the wave begin)
A wave	- Due to <u>A</u> trial contraction (Atrial kick)	- With P wave	- End of diastole
C wave	- Due to <u>i</u> sovolemic (isometric) RV Contraction which closes tricuspid valve cusps causing it to bow (elevated) back toward the RA. This increases RA pressure.	- After onset of QRS complex.	- Early systole.
X wave (x descent)	- Due to atrial relaxation and changing atrial geometry produced by downward displacement of RV during its contraction.	- With ST segment & T wave.	- Systole
V wave	- Due to <u>v</u> enous filling (<u>v</u> enous return) of RA against a closed tricuspid valve during isometric relaxation phase of RV.	- After T wave.	- Late systole.
y wave (y descent)	- Due to tricuspid valve opening to fill RV.	- After T wave to the onset of P wave.	- Diastole.

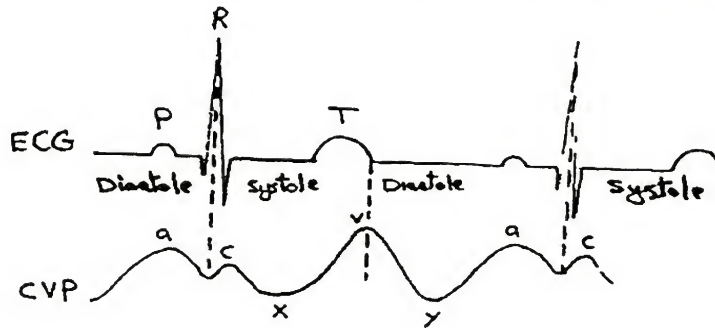


Figure 5-7; CVP & ECG relationship.

Technique of C.V Catheterization:

- Either by - Catheter-through-needle technique.
 - Seldinger technique or Catheter-over-Guideline technique (more easy, more sure & less traumatizing) .
- The central vein can be;
 - Basilic vein (at the medial side of antecubital fossa) (figure 5-8).
 - Cephalic vein (at the lateral side of antecubital fossa) (figure 5-8).
 - Subclavian vein (figure 5-9).
 - Internal jugular vein (figure 5-10).
 - External jugular vein.
 - Femoral vein (figure 5-11) (of choice during CPR as the physician inserting the catheter is away from the commotion around the thorax).

Complications of Central Venous Cannulation:

According to the nearby structures of the selected vein;

- 1- Trauma to **arteries** as: carotid, subclavian, femoral, or brachial.
- 2- Trauma to **nerves** as: brachial plexus, or stellate ganglion.
- 3- Trauma to **lung & pleura** as: pneumothorax, hemothorax, or pleural effusion so, chest X-ray is essential after insertion especially with subclavian.

MONITORING DURING ANESTHESIA

- 4- Trauma to **thoracic duct** as: chylothorax (left internal jugular approach).
- 5- Trauma to **mediastinum** as: mediastinal effusion.
- 6- Trauma to **heart** as: cardiac perforation, tamponade, dysrhythmias, or heart block.
- 7- Trauma to **vein itself** as: extravasation, extravascular migration, hematoma, thrombosis, or thrombo-embolism.
- 8- **Emboli** as: air, catheter, or wire.
- 9- **Catheter knotting and catheter fracture.**
- 10- **Infection**, sepsis and endocarditis.
- 11- Limitation of the movement in the site of insertion e.g. neck with internal or external jugular vein.

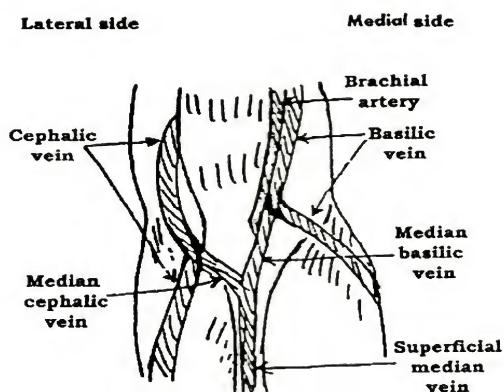


Figure 5-8; Antecubital fossa

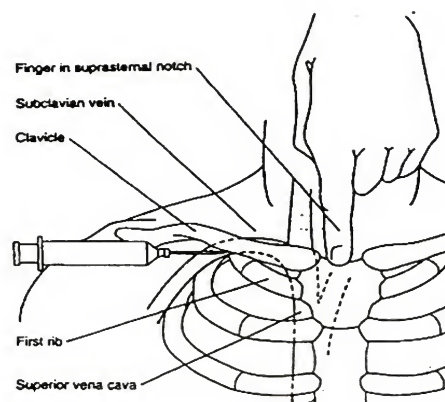


Figure 5-9; Subclavian vein cannulation

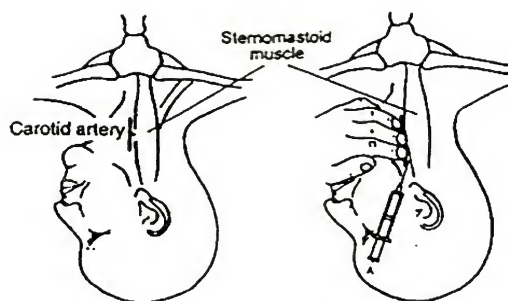


Figure 5-10; Internal jugular vein cannulation

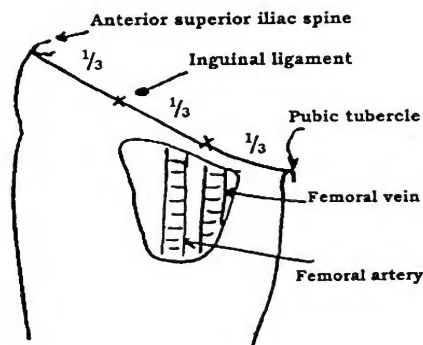


Figure 5-11; Femoral vein cannulation

VI- Pulmonary Artery Catheterization

(Pulmonary Artery Floatation Catheter or Swan-Ganz Catheter)

In 1970, Swan, Ganz & their colleagues described a catheter that could be floated into the pulmonary artery without the use of radiography or fluoroscopy.

Catheter Description:

- Flow-directed catheter.
- Material: polyvinyl chloride (PVC).
- Length: 110 cm (marked at 10 cm intervals to facilitate insertion).
- Size: 7 FG (double lumen). 7.5 FG (triple lumen).

- Balloon: 1.5 mL capacity usually.
- Lumens:
 - The simplest form of the catheter has two channels (one for inflation of the balloon and the other for measurement of pressure at the tip).
 - More sophisticated versions have 4 lumens (figure 5-12):

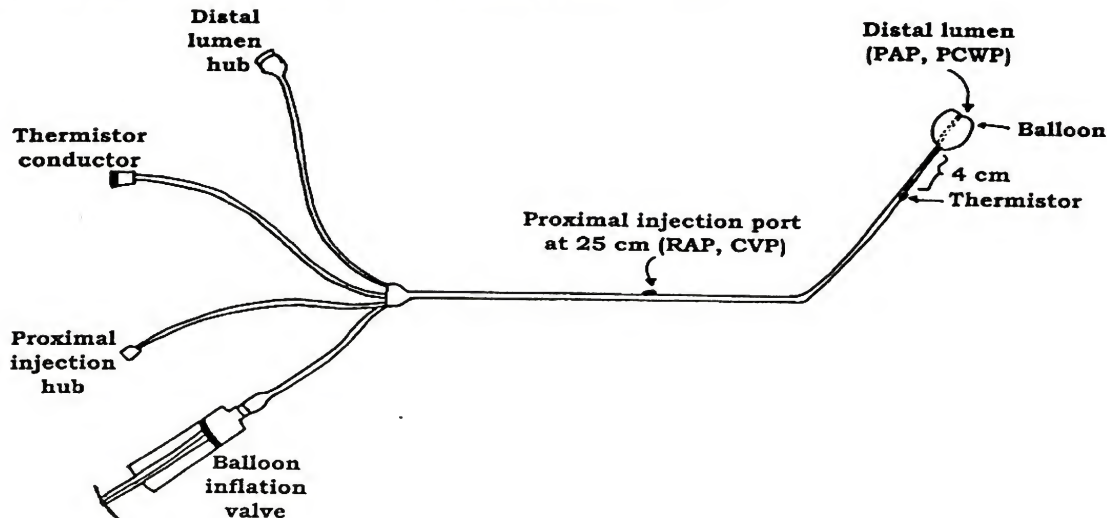


Figure 5-12; 4-lumens pulmonary artery catheter.

1- The Proximal Lumen:

- It ends at **25-30 cm** from the tip of the catheter.
- Its opening should lie in the **RA** after final placement of the catheter.
- It is used for
 - CVP and RAP measurement.
 - Fluid infusion.
 - CO injections.

2- The Distal Lumen:

- It ends at the catheter **tip**.
- Its opening should lie in a major branch of the pulmonary artery.
- It is used for
 - PAP measurement without wedging.
 - PCWP measurement with wedging.
 - Aspiration of mixed venous blood samples (\bar{v}).

3- The Balloon Lumen:

- It is used for inflation of the balloon by 1.5 mL air, the balloon surrounds the distal tip of the catheter. So, balloon inflation prevents the tip of the catheter to produce trauma.

4- The Thermistor Lumen:

- It ends **4 cm** from the distal tip where a bead thermistor is mounted. It measures blood temperature.
- It is connected by a wire to a computer for CO measurement.

Accessories: (Recent Advances in Pulmonary Artery Catheter)

1- **Fiberoptic channel** for measuring **O₂ saturation** in pulmonary artery blood (mixed venous O₂ saturation).

2- **Pacing leads** for intra-cavitary pacing.

3- **ECG electrodes** for intra-cavitary ECG.

4- **Continuous CO measurement:**

By **pulsed-thermodilution**. It is an injectless system which incorporates a thermal filament to provide intermittent periods of heat, which are sensed by a distal thermistor. These accessories are present only in specially designed catheter.

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- Before insertion,
 - The balloon is tested by inflation and deflation.
 - Irrigation of the proximal and the distal lumens with heparinized saline is done.
- The catheter is passed through a large-bore introducer catheter (8.5 FG) situated in the subclavian or internal jugular vein via the Seldinger technique.
- When the catheter tip emerges from the introducer and is exposed to the flowing blood, the balloon is inflated with 1.5 mL of air and the catheter is advanced slowly with the balloon to protect the endocardium from injury by the catheter tip.
- Connect the distal port to a transducer that is zeroed to the patient's mid-axillary line. By recording the pressure waveforms on advancing the catheter, we can identify the catheter tip position (figure 5-13).

1- When The Catheter Tip is in The SVC or RA: (nearly at 15 cm).

- The pressure in the SVC has a venous pattern and is called central venous pressure. It is equivalent to the RAP.
- CVP tracing varies with respiration, this confirms intra-thoracic position.

2- When The Catheter Tip is in the RV: (nearly at 25 cm)

- When the catheter tip crosses the tricuspid valve and enters the RV, a systolic pressure appears suddenly while the diastolic pressure remains the same.

During advancement, ECG monitoring is essential to detect arrhythmias as transient ventricular ectopy may occur from irritation of RV endocardium by the catheter which rarely needs i.v lidocaine.

3- When The Catheter Tip is in The PA: (usually at 35-45 cm)

- When the catheter tip crosses the pulmonary valve and enters the PA, the diastolic pressure suddenly rises and a dicrotic notch (due to closure of pulmonary valve) appears on the waveform. This is the PAP waveform.

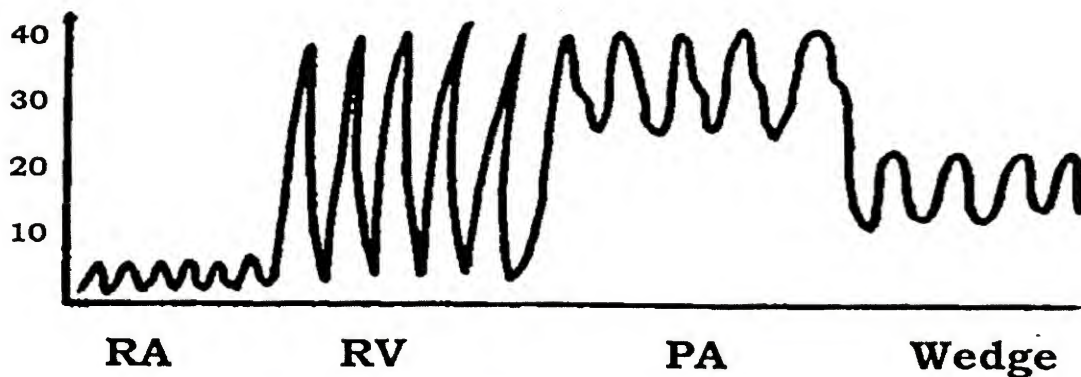


Figure 5-13; Pressure waveforms seen as the pulmonary artery catheter is advanced

Pressure	Normal values	Remarks
• RAP	0-5 mm Hg	- i.e. as CVP value
• RVP	15 - 30/ 0- 4 mm Hg	- There is systole, but no diastole.
• PAP	15- 30/ 6-12 mm Hg	- There is systole and diastole.
• PCWP	0-12 mm Hg	- Borderline is 13-17 & heart failure is > 18 mm Hg
• LAP	0-12 mm Hg	- The same as PCWP.
• LVP	120/ 0-8 mm Hg	- There is systole but no diastole.

4- When the Catheter Tip is Advanced Along the PA for a Short Distance:

- The systolic component of the pressure waveform will eventually disappear. This final pressure is called Pulmonary Capillary Wedge Pressure (PCWP) or Pulmonary Artery Occlusion Pressure (PAOP).
- Once PCWP is obtained, the balloon is deflated and the PAP waveform should reappear so, the balloon is kept fully deflated and PAP is continuously monitored except for brief periods of time to measure PCWP.
- Wedging before maximal balloon inflation indicates over wedged position so, catheter should be withdrawn slightly (with the balloon deflated) as this may cause PA rupture.
- The frequency of PCWP measurement should be minimal.

Precautions:

- Never withdraw the catheter while the balloon is inflated. And never introduce the catheter while the balloon is deflated.
- To avoid catheter knotting, the balloon should be deflated and the catheter should be withdrawn if the pressure changes do not occur at the expected distances.
- Correct position is confirmed by lateral chest X-ray to detect abnormal catheter migration to the vena cava anteriorly.

Indications:

1- Cardiac Causes: before cardiac and non cardiac surgery when there is **dissociation between left and right sided hemodynamics** i.e. between LAP (PCWP) and RAP (CVP) which occurs in:

- **Poor LV function (failure)** with: $EF < 0.5$, $LVEDP > 15$ mmHg, cardiac index $< 2 \text{ L / min / m}^2 \pm$ pulmonary edema e.g. cardiomyopathy, pericardial tamponade, and severe toxemia of pregnancy
- **Severe valvular heart diseases.**
- **Severe coronary artery disease** or recent myocardial infarction (< 6 months duration).
- **Pulmonary edema** of any cause.
- **VSD** as O_2 saturation of RV is $> RA$.

2- Pulmonary disease:

- a- Acute respiratory failure as pulmonary emboli, ARDS, or pulmonary hypertension.
- b- Severe COPD and cor pulmonale.

3- Complex Fluid Management:

As • Shock: septic, cardiogenic, or hypovolemic.

- Major fluid shift &/or loss e.g. placental abruption, burns, polytrauma and acute renal failure.

4- Specific Surgical Procedures:

- CABG.
- Valve replacement.
- Pericardiectomy.
- Aortic cross clamping (e.g. aortic aneurysm repair).
- Sitting craniotomy to detect air embolism.
- Portal systemic shunts (e.g. liver transplantation).

5- With Special Therapy:

- Inotropic therapy.
- Intra-aortic balloon pump.
- Mechanical ventilation with high level of PEEP.

MONITORING DURING ANESTHESIA**Contraindications** (relative):**1- Cardiac Causes:**

- Tricuspid or pulmonary valve disease / replacement.
- Recent pacemaker insertion.
- Ventricular arrhythmias.
- Left bundle branch block as may cause complete heart block so, use catheter with pacing capability.

2- Catheter Causes:

- Coagulopathy as the catheter may cause bleeding.
- Hypercoagulopathy as the catheter acts as a nidus for the thrombus formation.
- Septic patients, as the catheter acts as a nidus for infection.

Value:**A- Measurement of Hemodynamic Parameters:****1. Central Venous Pressure (CVP):**

- It is the pressure recorded from the proximal port of the catheter situated in the right atrium.
- RAP should be equivalent to right ventricular end-diastolic pressure (RVEDP) unless there is an obstruction between the atrium and the ventricle i.e. CVP = RVEDP, and it can indicate the left side except if there is a dissociation between the left and the right side (as above).

2. Pulmonary Artery Pressure (PAP):

- It is the pressure recorded from the distal port of the catheter situated in the distal part of the PA while the balloon is deflated.

3. Pulmonary Artery Occlusion Pressure (PAOP),**Or Pulmonary Capillary Wedge Pressure (PCWP):**

- It is the pressure recorded from the distal port of the catheter when the balloon is lodged in the distal part of the PA while it is inflated.
- This pressure is considered the left sided cardiac filling pressure and is considered equivalent to the left atrial pressure or LVEDP
i.e. PCWP = LAP = LVEDP → LVED volume.

4. Cardiac Output (CO): (SV x HR)

CO can be measured by **thermodilution** technique by the thermistor located 4- cm from the catheter tip.

B- Derived (Calculated) Hemodynamic Parameters:

- **Ejection Fraction (EF)** = ratio of stroke volume to end-diastolic volume.

$$= \text{EDV} - \text{ESV} / \text{EDV}$$

$$= \text{SV} / \text{EDV}$$

$$= 0.56 - 0.75 \text{ (56-75 \%)}$$

- **Cardiac Index (CI)** = $\frac{\text{CO (L/min)}}{\text{Body surface area (m}^2\text{)}}$ = 2.2 – 4.2 L / min / m²

- **Stroke Volume (SV)** = $\frac{\text{CO (L/min)} \times 1000}{\text{Heart Rate (beats/min)}}$ = 60 – 90 mL / beat

Other derived hemodynamic parameters;

- **Stroke Volume Index (SVI).**
- **Left Ventricular Stroke Work Index (LVSWI).**
- **Right Ventricular Stroke Work Index (RVSWI).**
- **Systemic Vascular Resistance** (total peripheral resistance i.e. venous & arterial).

- Systemic Vascular Resistance Index.
- Pulmonary Vascular Resistance.
- Pulmonary Vascular Resistance Index.

C- Other Variables With Sampling of Mixed Venous Blood:

1- O₂ Delivery (D'O₂) = O₂ Flux

- It is the amount of O₂ delivered to the capillaries / minute.

$$\begin{aligned}
 - D'O_2 &= CO \times CaO_2 \quad \text{mL/min} \\
 &= CO \times \left(\text{Chemical combined with Hb} + \text{Physical dissolved in plasma} \right) \\
 &= CO \times \left([Hb \text{ gm/dL} \times 1.38 \times SaO_2 \text{ \%}] + [0.003 \times PaO_2 \text{ mm Hg}] \right) \\
 &= CO \times \left([15 \times 1.38 \times 97/100] + [0.003 \times 95] \right) \\
 &= CO \times 20.6 \text{ mL/dL} \\
 &\text{as } [0.003 \times PaO_2 \text{ mm Hg}] \text{ is of little value so, it has a little effect.} \\
 \text{So, } D'O_2 &= CO \times Hb \text{ gm/dL} \times 1.38 \times SaO_2 \\
 &= 850-1050 \text{ mL/min}
 \end{aligned}$$

N.B.;

- 1.38 means that each one gram % of Hb when it is 100 % saturated can carry 1.38 mL of O₂.
- 0.003 is the O₂ solubility coefficient i.e. at partial pressure of O₂ equal one, the amount of O₂ that dissolve in plasma is 0.003 mL.
- O₂ content in arterial blood (CaO₂) = 20.6 mL/dL.

NB; CaO₂ = Arterial O₂ content.

C \bar{u} O₂ = mixed venous O₂ content.

SaO₂ = Arterial O₂ saturation.

C \bar{c} O₂ = O₂ content in end pulmonary capillary.

2- O₂ Uptake (V'O₂): by tissue = O₂ consumption (Fick's equation).

- It is the amount of O₂ taken up from the capillaries /minute.

$$\begin{aligned}
 V'O_2 &= CO \times (CaO_2 - C\bar{u}O_2) \quad \text{mL/min} \\
 &= CO \times Hb \times 1.38 \times (SaO_2 - S\bar{u}O_2) \\
 &= 250 \text{ mL/min}
 \end{aligned}$$

N.B.;

- During exercise V'O₂ (maximum) occurs. Healthy individuals can increase both CO and the difference (SaO₂-S \bar{u} O₂) by a factor of 3

$$\begin{aligned}
 V'O_2 \text{ (maximum)} &= 5000 \times 15 \times 1.38 (98/100 - 31/100) \times 3 \\
 &= 2080 \text{ mL/min.}
 \end{aligned}$$

I.e. V'O₂ can be increased up to 9 folds.

- O₂ content in mixed venous blood (C \bar{u} O₂) = 15.6 mL/dL.

3- O₂ Extraction Ratio (O₂ER):

- It is the ratio of O₂ uptake to O₂ delivery rate.

$$\begin{aligned}
 O_2 \text{ ER} &= V'O_2 / D'O_2 \\
 &= 20 - 30 \% \text{ Normally.}
 \end{aligned}$$

4- Mixed Venous O₂ Saturation (S \bar{u} O₂):

- It is the amount of O₂ combined to Hb in the pulmonary artery.

- Normal value = 75 %

$$S\bar{u}O_2 = SaO_2 - \frac{V'O_2}{CO \times Hb \times 1.38} \quad \text{as derived from Fick equation}$$

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So, from the equation $\bar{S}\bar{V}O_2$ is directly proportionate to SaO_2 , CO, Hb
& inversely proportionate to $V'O_2$

So, Decreased $\bar{S}\bar{V}O_2$ indicates;

- An increased O_2 consumption or tissue uptake i.e. increased $V'O_2$
- A decrease in one of the component of O_2 delivery
 - E.g. - Decreased SaO_2 as hypoxemia.
 - Decreased CO
 - Decreased Hb % as anemia.

Increased $\bar{S}\bar{V}O_2$ indicates;

- A decreased O_2 consumption as - Hypothermia
 - Histotoxic hypoxia (carbon monoxide or cyanide poisoning).
- An increase in one of the components of O_2 delivery
 - E.g. - Increased SaO_2 as hyperoxia, sampling during wedged catheter or rapid aspiration of PA blood sample although the catheter is not wedged.
 - Increased CO as sepsis, porto-caval shunt, A-V fistula, Paget's disease of the bone, increase dose of inotropic drugs.
 - Increased Hb % as polycythemia.

5- Intrapulmonary Shunt Equation:

$$= \frac{C\bar{c}O_2 - C\bar{a}O_2}{C\bar{c}O_2 - C\bar{v}O_2} \quad \text{Or} \quad = \frac{1 - SaO_2}{1 - \bar{S}\bar{V}O_2}$$

$C\bar{c}O_2$ is measured by pulmonary artery catheter during wedging.

Complications:a. Complications of Central Venous Cannulation:

as before in CVP.

b. Complications Specific to the Swan-Ganz Catheter:1- Heart:

- Pulmonary and tricuspid valve trauma.
- Tricuspid incompetence.
- Ventricular arrhythmias.
- Complete heart block.

2- Lung:

- Pulmonary infarction (due to continuous wedging).
- Pulmonary hemorrhage especially in anticoagulated patient.
- Pulmonary artery rupture especially in elderly female or pulmonary hypertension.

3- Balloon:

- Rupture.
- Transient hypotension and hypoxemia with balloon inflation.

VII- Cardiac Output (CO) Measurement:Indications:

The same as pulmonary artery catheterization.

Contraindications:

The same as pulmonary artery catheterization.

Value:

Many indices are derived from CO "see pulmonary artery catheterization".

Technique:**A- Invasive Techniques:****1- Fick Principle:**

It is the standard method of measurement of CO as the amount of a substance taken up by an organ / min = (arterial level of this substance – its venous level) x blood flow / min.

So, O₂ consumption can be used

$$\text{As } \dot{V}O_2 = \dot{Q} \times (\text{CaO}_2 - \text{C}\bar{\text{v}}\text{O}_2)$$

$$\text{So, } \dot{Q} = \frac{\dot{V}O_2}{\text{CaO}_2 - \text{C}\bar{\text{v}}\text{O}_2} = \frac{250 \text{ mL/min}}{(20.6 - 15.6) \text{ mL/dL}} = 5 \text{ L/min}$$

$\dot{V}O_2$ = O₂ consumption which is calculated from the difference between O₂ content in inspired & expired gas.

\dot{Q} = Blood flow = Cardiac output.

CaO₂ = Arterial O₂ content which is obtained from arterial line.

C $\bar{\text{v}}$ O₂ = Mixed venous O₂ content which is obtained from pulmonary artery catheter.

Also CO₂ production can be used.

2- Thermodilution:

- Injection of a quantity (2.5, 5 or 10 mL) of fluid (5% glucose) at below body temperature (either room temperature, or iced) into RA changes the temperature of blood in contact with the thermister in the pulmonary artery.
- The degree of change is inversely proportionate to the cardiac output:
If the temperature change is minimal so, there is high blood flow
& If the temperature change is maximal so, there is low blood flow.
- Plotting the temperature changes with time produces a **thermodilution curve**.
- CO is determined by a computer program that integrates the area under the curve.

3- Dye Dilution:

- **Indocyanine green dye** (metabolized by liver) is injected via a central venous catheter, its appearance in the arterial circulation can be measured by analyzing arterial samples with a densitometer, or recently fiberoptic densimeter into the catheter is used.
- The area under the resulting dye indicator curve is related to CO.
- This method has a problem of indicator **recirculation**, arterial blood sampling and background tracer buildup.

B- Non-Invasive Techniques:**1- Ultra-sonography:**

E.g. Trans-esophageal Echocardiography. "See later"

2- Thoracic Bio-impedance:

- Changes in thoracic volume leads to changes in thoracic resistance (bio-impedance).
- This technique needs 4 pairs of ECG electrodes to inject micro-currents and to sense bio-impedance on both sides of the chest.

3- Pulse Contour Analysis (Arterial Waveform):

- As the rate at which blood flows from arteries to veins is proportional to the rate of fall of BP. The analysis of the contour of arterial pulse wave obtained non-invasively by plethysmography or invasively by arterial cannula can be used for CO monitoring.

VIII- Trans-esophageal Echocardiography (TEE)

Principles:

- Ultrasound is sound above the upper threshold of human hearing (20 000 Hz).
 - Ultrasound waves (1 – 7 MHz) are created by **piezo – electric crystal**.
 - The U/S pulses are directed to tissues then **partially reflected** at the boundaries of different structures of **different acoustic impedance**. This is called pulsed reflected ultrasound So, when directed to the heart it is called cardiac ultrasound or echocardiography.
 - **Pulsed doppler**: when these U/S waves are directed to moving objects e.g. RBCs in blood vessels, the velocity of these objects can be known by the shift in the reflected frequency of an U/S wave. With knowing the cross – sectional area of the vessels e.g. aorta by trans-esophageal echocardiography the stroke volume and CO can be known.
- N.B.; In 1841, Christian Doppler noted the change in observed frequency from a constant frequency sound generator when the source moved with respect to the observer. Ballot confirmed this Doppler effect in 1845 with the simple example of the frequency increase in a train's stream whistle as the train approached an observer.
- TEE is an U/S transducer which is mounted on the end of a flexible endoscope. It is inserted into esophagus at 35 – 40 cm. **The patient** should be **anesthetized** so, it is unsuitable during induction and intubation. Before its introduction, a gastric tube is introduced to suction out excessive stomach content and air.

Clinical Applications:

1. Assessment of C.V.S Pathology:

- It can assess the pathology **pre-, intra-, and postoperatively** where it can assess the adequacy of the repair.
 - It assesses **global ventricular function** (systolic or diastolic, LV or RV or both)
- Also, it assesses **regional ventricular function** i.e. Segmental Wall Motion Abnormality (SWMA).

As - **Aortic injury or dissection.**

- **Aortic atheroma.**
- **Air embolism.**
- **Valvular diseases**
- **Congenital heart disease.**
- Cardiac tumors as **LA myxoma** .
- During CABG surgery.

2. Assessment of Hemodynamics:

It can detect;

- **LV preload and LV contractility.**
- **LV filling pressure (LA pressure).**
- **Cardiac output** (as $CO = \text{stroke volume} \times \text{heart rate}$)
- **Acute hypotension:**

It is used as a guide for administration of i.v. fluids inotropes and vasopressors.

It allows early detection of decreased preload before it leads to significant hypotension.

3. Detection of Ischemia:

- Ischemic segments of the heart do not contract normally.
- During acute ischemia, **segmental wall motion abnormalities (SWMA)** occur within seconds of the onset of ischemia. It precedes and may occur without ST segment changes i.e. **TEE has more advantage than ECG.**
- The classes of SWMA are:

Class of Motion	Wall Thickening
1- Normal	Marked
2- Mild hypo-kinesis	Moderate
3- Severe hypo-kinesis	Minimal
4- Akinesis	None
5- Dys-kinesis (paradoxical)	Thinning

Role of TEE in non-cardiac surgery:

- 1- High risk major general surgeries.
- 2- Vascular surgeries.
- 3- Eclamptic patients.
- 4- Neurosurgeries.
- 5- Postoperative in PACU or ICU.

In these surgeries, TEE is used to assess;

- CVS pathology as air embolism.....etc.
- Hemodynamics as CO and causes of hypotension.....etc.
- Myocardial ischemia as SWMA.....etc.

IX: Measurement of Blood Loss:

- Losses > 15 % in adults and > 10 % in pediatrics should be replaced by blood.
- Measurement of blood loss is done by;
 - 1- Assessing the blood amount in **suction jars** (after subtracting washing fluids).
 - 2- Assessing the number of either fully or partially soaked **surgical swabs** according to their size.
 - 3- **Weighing** surgical swabs before (dry) and after (soaked) surgery, especially in children, but this method is still inaccurate as it ignores blood lost on drapes, gowns ... etc, and water evaporation.
 - 4- A more accurate method's by **colorimetry**, as swabs, gowns and drapes are washed with a known volume of fluid and the Hb content is measured colorimetrically, this method can be performed at the end of the procedure.

Respiratory System Monitors

They include;

- I- Clinical monitoring.
- II- Measurement of airway pressure.
- III- Disconnection alarm.
- IV- Precordial & esophageal stethoscope.
- V- Spirometry.
- VI- O₂ monitoring.
- VII- CO₂ monitoring.
- VIII- Anesthetic gas analysis.
- IX- Measurement of H⁺ ions.

I - Clinical Monitoring

It is the most important. It includes;

- 1- Patient's color.
- 2- Respiratory rate.
- 3- Adequacy of chest movement.

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- 4- Movement of the reservoir bag or ventilator bellows.
 - 5- Frequent auscultation of both lung fields by binaural stethoscope to detect
 - Quality of air entry, (obstruction, pneumothorax).
 - Intubation of bronchus.
 - Presence of secretions.
 - Wheeze (bronchospasm).
 - + - Heart rate regularity.
 - Heart tones as muffled tones are associated with decreased CO (especially in pediatrics).
 - 6- Some ventilators make a regular noise during part of the ventilatory cycle which is a valuable audible monitor.
- N.B.: - Signs of respiratory obstruction:
- Nasal flaring.
 - Tracheal tug.
 - Stridor: Inspiratory → extra-thoracic cause.
Expiratory → intra-thoracic cause.
 - No bag inflation.
 - Paradoxical abdominal movement.

II- Measurement of Airway Pressure:

- By a simple manometer incorporated in either the breathing circuit or the mechanical ventilator.
 - **Causes of Increased Airway Pressure:**
- 1- Mechanical:
 - Kinking of ventilator tubing or tracheal tube.
 - Over-inflation of tracheal cuff causing obstruction of the lumen of the tube.
 - 2- Decreased lung compliance:
 - Secretions.
 - Bronchospasm.
 - Pneumothorax.
 - 3- Decreased chest compliance:
 - Inadequate muscle relaxation.
 - Surgical manipulation.
 - Patient's position.

III- Disconnection Alarm:

- The alarm is activated if the airway pressure decreases below a preset minimum for a preset time interval e.g. leak, disconnection. Some of these devices also give alarm if excessive airway pressure is generated.

IV- Precordial & Esophageal Stethoscope:**Indications:**

- It can be used in all anesthetized patient, especially because it is cheap, non-invasive and free from electrical interference.

Contraindications:

- Esophageal varices or strictures.

Technique:**A- Precordial Stethoscope (Wenger Chest Piece):**

- It is heavy, bell-shaped piece of metal placed over the chest or supra- sternal notch (figure 5-14). It has different sizes.
- It is fixed by double-sided adhesive disks which
- provide an acoustic seal to the patient's skin.

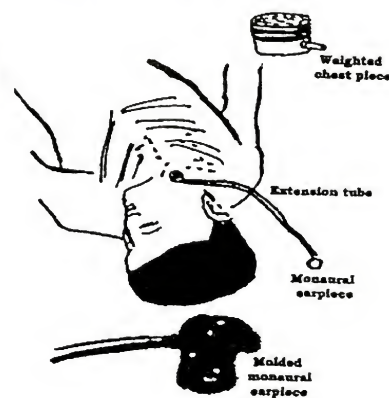


Figure 5-14; Precordial stethoscope

- A molded monaural earpiece allows simultaneous monitoring of the stethoscope and operating room environment.

B- Esophageal stethoscope:

- It is a soft plastic catheter (8-24 F) with a balloon-covered distal opening and a molded ear-piece (figure 5-15).
- Its use is limited to intubated patients.
- In some designs, there are.
 - Temperature probes.
 - ECG leads.
 - Atrial pacemaker.

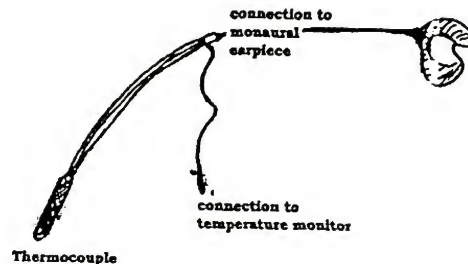


Figure 5-15; Esophageal stethoscope

V- Spirometry:

Indications:

- 1- Patients receiving IPPV.
- 2- Patients are likely to have affected respiratory mechanics.
 - As - One lung anesthesia.
 - Severely asthmatic patients.

A- Wright Respirometer (Main Stream):

It measures inspired and expired volumes.

B- Side Stream Spirometry:

- It gives continuous real time measurement of gas pressure and volume. Both are based on the measurement of kinetic gas pressure using the **Pitot effect**.

VI- O₂ Monitoring:

A- O₂ Delivery to The Patient:

It includes;

- 1- O₂ failure alarm.
- 2- Detection of inspired O₂ concentration in gas mixtures.
 - Fuel cell (Galvanic O₂ analyzer).
 - Clark electrode (Polarographic) (O₂ electrode).
 - Paramagnetic analyzer.

B- O₂ Delivery to The Tissues: (Monitoring of Tissue Oxygenation):

Physiology:

$$\begin{aligned}
 - D'O_2 &= CO \times CaO_2 \text{ mL/min} \\
 &= CO \times \left([Hb \text{ gm/dL} \times 1.38 \times SaO_2 \text{ \%}] + [0.003 \times PaO_2 \text{ mm Hg}] \right)
 \end{aligned}$$

- O₂ - Hb dissociation curve....."see later".

It includes;

I- Global Tissue Oxygenation:

1- Clinical Monitoring:

Tissue perfusion....."see before"

2- O₂ Delivery (Transport) Monitoring:

- 1- CO by •CO measurement • ABP • CVP • PAP • PCWP.
- 2- Hb level.
- 3- SaO₂ by pulse oximetry.
- 4- PaO₂ (O₂ tension) by • Miniature Clark electrode.

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- Fiberoptic O₂ sensor.
- Trans-cutaneous O₂ tension.....
- Conjunctival O₂ tension.....

3- O₂ Uptake Monitoring:

- 1- S \bar{V} O₂ by pulmonary artery oximetry.
- 2- Serum lactic acid measurement.

II- Regional Tissue Oxygenation:

- 1- Subcutaneous and intravenous oximetry.
- 2- Cerebral oximetry.
- 3- Gastric intra-luminal tonometry.

Pulse Oximetry**Value:**

- 1- It measures O₂ saturation of Hb in arterial blood.
- 2- It measures heart rate.
- 3- It gives an idea about tissue perfusion by pulse waveform.
 - Increased pulse amplitude indicates VD.
 - Decreased pulse amplitude indicates VC or hypovolemia.
 - Area under the curve indicates stroke volume.
 - The dicrotic notch descends down with VD.

So, the pulse oximeter can be used for assessment of blood flow e.g. in a revascularized limb or a reanastomosed limb or digit after or during surgery.

Principles:

Based on Transmission Spectrophotometry & Plethysmography.....see physics.

Other Types of Oximeters:**1- Co-oximeters (Hemoximeter):**

- It is a transmission oximetry. It is in vitro oximetry capable of transmitting 4-6 or more wavelengths of light through a blood sample. It is capable of detection of oxy-Hb, deoxy-Hb, CO-Hb, met-Hb, and other dys-Hb as sulf-Hb.

2- Mixed Venous Oximeters (Pulmonary Artery Oximetry):

- It allows continuous monitoring of O₂ saturation in the mixed venous blood (S \bar{V} O₂) in pulmonary artery through a specialized pulmonary artery catheter equipped with fiberoptic bundles that can transmit light of 3 wavelengths to and from the catheter tip.
- It is a reflection spectrophotometry and not a transmission spectrophotometry.
- If the fiberoptic sensor is placed in the internal jugular vein, measurement of jugular bulb O₂ saturation occurs so, it can assess the adequacy of cerebral O₂ delivery e.g. during carotid endarterectomy (Intravascular Oximetry).
- Also, if it is placed in supra-hepatic vein, measurement of hepatic O₂ saturation occurs so, it can assess adequacy of hepatic O₂ delivery e.g. during hepatic surgery (Intravascular Oximetry).

Q: Discuss pulmonary artery oximetry ?

A: Discuss the following items;

- Physiology of O₂ transport.
- Principles of action of pulse oximetry.
- Factors increase or decrease S \bar{V} O₂ "see before".

3- Cerebral Oximeter:

- It monitors regional O_2 saturation of Hb in the brain (rSO_2).
- A sensor is placed over the forehead and emits light of a specific wave-length. It measures light reflected back to the sensor (near infrared spectroscopy) (**Reflection spectroscopy**).
- Cerebral oximetry measures venous and capillary blood O_2 saturation in addition to arterial blood O_2 saturation (unlike pulse oximetry). Therefore, it measures the average O_2 saturation of all regional micro-vascular Hb ($\approx 70\%$)

Gastric Intra-luminal Tonometry

- To detect splanchnic hypoperfusion manifested by splanchnic tissue acidosis (early sign).
- It is used to measure intra-mucosal pH of gastric mucosa (indirect measurement).

- Principles: -

- Intra-luminal PCO_2 is equivalent to the PCO_2 in the gastric mucosa and the concentration of intra-mucosal HCO_3^- is equivalent to that in arterial blood.
- Splanchnic hypoperfusion causes tissue acidosis which increases concentration of intra-mucosal CO_2 and PCO_2 . CO_2 diffuses to the gastric lumen and equilibrates with saline filled silastic tonometry balloon permeable to CO_2 . The silastic balloon is placed in the stomach (figure 5-16).
- By measuring the arterial HCO_3^- concentration and utilizing **Handerson-Hasselbach equation**, intra-mucosal pH can be calculated.

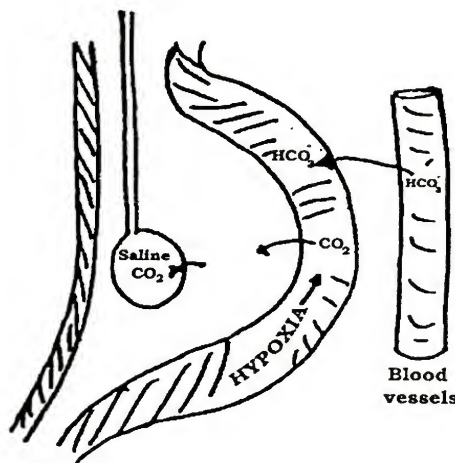


Figure 5-16; Gastric intra-luminal tonometry

$$pHi = 6.1 + \text{Log} \frac{[HCO_3^-]}{0.03 PCO_2}$$

Where: 6.1 = pKa of H_2CO_3 system.
 $[HCO_3^-]$ = Arterial plasma HCO_3^- concentration.
 PCO_2 = CO_2 tension of saline in the balloon.
 0.03 = Solubility coefficient of CO_2 .

VII- CO_2 Monitoring:

It includes :

- A- CO_2 Excretion in Expired Gas : Capnography .
- B- CO_2 Excretion in Tissues (PCO_2): Severinghaus CO_2 Electrode
Trans-cutaneous Partial Pressure of CO_2 .

End-Tidal CO_2 (ET CO_2) Analysis (Capnography)

Indications:

- 1- **Essential** in all anesthetized patients because;
 - It confirms adequate ventilation.

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- It detects esophageal intubation (the most reliable sign).
- 2- Ventilator control to **maintain normocapnia for adequate cerebral perfusion** in;
 - Intracranial hypertension.
 - Carotid artery surgery.
- 3- Diagnosis of **air embolism** (causing rapid fall of CO_2).
as in sitting craniotomy etc.

Normal CO_2 Waveform

- **Phase I:** dead space (both mechanical and anatomical)(no CO_2).
- **Phase II:** mixture of dead space and alveolar gas.
- **Phase III:** Alveolar gas plateau (figure 5-17).

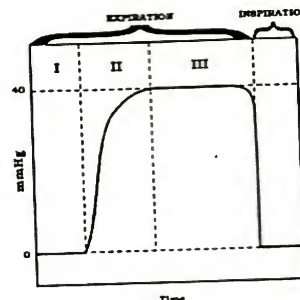


Figure 5-17; Normal CO_2 Waveform

Values:

By studying the shape of CO_2 waveform:

1- **Sudden cessation** of end-tidal CO_2 waveform:

- It indicates • **Circuit disconnection.**
or • **Cardiac arrest.**

2- CO_2 level:

- **Increased CO_2 values:**

It indicates • **Incorrect calibration.**

- Any causes of **hypercarbia** e.g. inadequate ventilation or malignant hyperthermia ($\text{ETCO}_2 > 50$ mm Hg).

- **Decreased CO_2 values:**

It indicates • **Incorrect calibration.**

- Any causes of **hypocarbica** e.g. hyperventilation, hypothermia.
- Increased $P_a - P_A$ (increased $P_a - P_{\text{ETCO}_2}$) gradient "see later".

3- **Absence of phase III** (i.e. no plateau)

& **Decreased ET CO_2 with increased $P_a - P_A$ (increased $P_a - P_{\text{ETCO}_2}$) gradient**

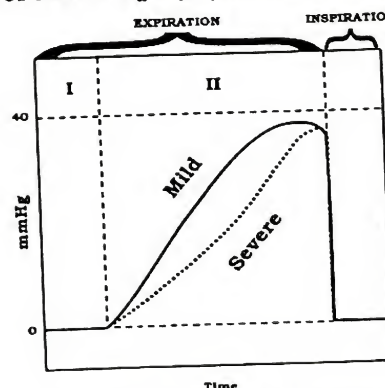


Figure 5-18; Absence of phase III OF CO_2 waveform

Both indicate either (figure 5-18);

a- **COPD, bronchospasm or mechanical obstruction to exhalation:** the severity of the obstruction is inversely related to the rate of rise of ET CO₂ i.e. more slope = more obstruction.

b- **V/Q mismatching** (decreased lung perfusion):

Normally, P_{ET} CO₂ or P_A CO₂ is less than PaCO₂ by 2-5 mm Hg. This gradient reflects alveolar dead space i.e. alveoli that are ventilated, but not perfused. So, decreased lung perfusion e.g. air embolism, upright position, decreased CO and decreased ABP increase alveolar dead space. The increased alveolar dead space dilutes expired CO₂ and decreases CO₂ excretion causing decreased ET CO₂. This increases the gradient between P_{ET} CO₂ and PaCO₂.

4- Depression during phase III (figure 5-19):

It indicates • **Spontaneous respiratory efforts.** • **Curare cleft (incomplete paralysis).**

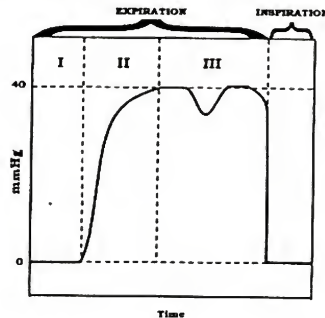


Figure 5-19; Depression during phase III

5- Failure of the inspired CO₂ to return to zero (i.e. CO₂ during all inspiration) (figure 5-20):

It indicates; • **Incorrect calibration to zero.**

• **Incompetent expiratory valve.**

• **Failure of CO₂ absorbent** (channeling, exhaustion, bypass) i.e. rebreathing.

• **CO₂ delivery to breathing system via fresh gas flow.**

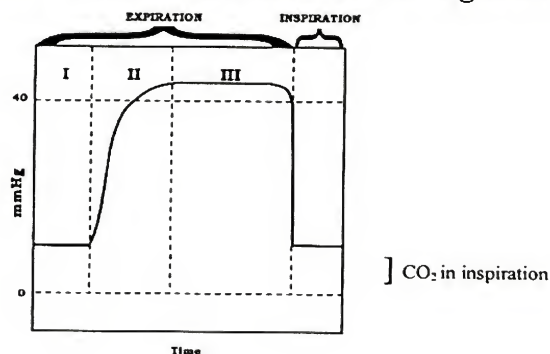


Figure 5-20; Failure of CO₂ to return to zero

6- Persistence of expired CO₂ during the first part of the inspiratory cycle (i.e. CO₂ during inspiration too) or prolonged inspiratory down stroke (figure 5-21):

It indicates; • **Incompetent inspiratory valve.**

• **Rebreathing.**

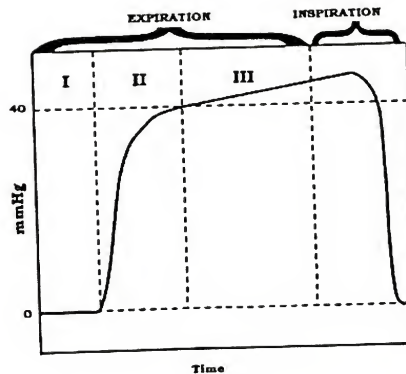
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Figure 5-21; Persistence of expired CO₂ during the first part of the inspiratory cycle

7- Gradual decrease in CO₂ waves until they disappear completely (figure 5-22):
It indicates; • **Esophageal intubation** as CO₂ that has been insufflated into the stomach during bag-mask ventilation is washed out during esophageal ventilation within a few breathes.

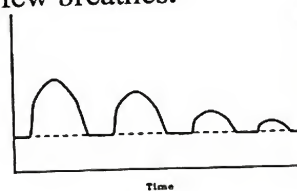


Figure 5-22; CO₂ waveform of esophageal intubation

8- During Cardio-Pulmonary Resuscitation (CPR):

Patients with cardiopulmonary arrest or low perfusion states and patients with respiratory stress have lack of circulation therefore, no CO₂ trace occurs (they should be differentiated from esophageal intubation), but on return of spontaneous circulation, there is increased exhaled CO₂ due to increased pulmonary blood flow. **During CPR** this sign can be used to indicate the **prognosis or the efficacy of resuscitation**.

- If there is exhaled CO₂ > 10-15 mm Hg, patients are likely to be resuscitated i.e. there is usually a good prognosis or adequate CPR so, continuing CPR is useful.
- If there is exhaled CO₂ < 10-15 mm Hg, patients are unlikely be resuscitated i.e. there is usually a bad prognosis or inadequate CPR so, continuing CPR is not useful.

Principles: Infrared absorption spectrophotometry.see physics.

CNS Monitors

It includes;

- I- Clinical monitoring.
- II- EEG.
- III- Evoked potentials.
- IV- Cerebral blood flow measurement.
- V- Monitoring of depth of anesthesia.

I- Clinical Monitoring:

A- Glasgow Coma Scale:

It is used pre-, or post-operatively "see later".

B- To Assess The Depth of General Anesthesia:

..... "see later".

C- Awake Test or Wake Up Test:

- The patient is either anesthetized by **regional techniques** or allowed to wake up during surgery and then asked to **respond to a verbal command**.

- Indications:

1- **Cerebral surgery for resection of a seizure focus.**

2- **Carotid endarterectomy.**

The test is done before, 1 and 2 minutes **after clamping** of the carotid artery as contra-lateral motor function is assessed.

3- **Surgical correction for scoliosis.**

To assess the anterior spinal cord **motor pathways**.

- Values:

1- Simple and inexpensive.

2- It can test areas of the brain that **are not assessed** by electro-physiological methods e.g. speech.

3- It is a **reliable and sensitive test**. It is **affected** when cerebral blood flow is reduced to **25 cc/min/100gm brain tissues**. It is **more sensitive** than EEG and SSEPs because they are affected when CBF is reduced to **15-20 cc/min /100 gm brain tissues**.

II- Electroencephalography (EEG)

Types:





A-Unprocessed Raw EEG:

- It records the **intrinsic electric activity of CNS neurons**.

- Disadvantages:

- It is difficult to interpret requiring **specially trained personnel**.
- Difficult in obtaining a **meaningful recording** in the electrically noisy environment of OR.
- The bulk of the equipment required.

- EEG waveforms:

Rhythm	Frequency (Hz)	Amplitude (μ v)	
Beta (β)	14-30 (fastest)	< 20	
Alpha (α)	8-13	20-50	
Theta (θ)	4-7	20-50	
Delta (δ)	< 4 (slowest)	> 50	

MONITORING DURING ANESTHESIA:

- In relaxed adults with closed eyes, α rhythm predominates.
- With eye opening i.e. any sensory stimulation "excitation or arousal", fast irregular low voltage activity with no dominant rhythm called **α block or de-synchronization** predominates.
- In children, θ rhythm predominate.
- In non-rapid eye movement (NREM, deep) sleep, large irregular δ waves interrupted by α like activity predominates.
- In rapid eye movement (REM, paradoxical) sleep, low voltage irregular rapid waves predominate.

B- Processed EEG:

- Various methods of signal processing and computer-assisted data analysis have been developed which compress the data and make interpretation easier and more acceptable.
- These include;

1- Cerebral Function Monitor (CFM):

- It compresses all frequencies and amplitude information in the EEG into a single value.

2- Cerebral Function Analyzing Monitor (CFAM):

- It provides analysis of both the amplitude and frequency.
- It displays a percentage of each band (α , β , θ , δ).

3- Power Spectrum Analysis:

- It retains all information from the original EEG, changing the complex waveforms of unprocessed EEG into a number of standard waves for easy comparison.
- It studies the EEG at short time intervals, known as epochs (2-16 s).

4- Bi-Spectral Analysis (Bi-Spectral Index) (BIS):

It is the most recent. EEG information is collected and analyzed producing **BIS scale** from 0 to 100

Where	95-100	= Fully awake.
	> 90	= Intact reflexes (i.e. patient can be extubated).
	70-85	= Light to moderate sedation.
	40-60	= Adequate depth of anesthesia
	< 40	= Deep anesthesia.
	0	= Isoelectric line of EEG.

It is a valid predictor of hypnosis and possibility of intraoperative awareness. Therefore, it is a valid predictor of the depth of anesthesia.

Limitations of BIS Index:

- 1- The BIS is only a measure of the patient's level of sedation and hypnotic state.
- 2- It does not predict patient movement or hemodynamic responses to noxious stimulation.
- 3- It will not predict the exact moment when consciousness will return because it is not a measure of global anesthesia depth.
- 4- Sedation produced by both ketamine and N_2O do not produce the expected decrease in BIS.

Factors Affecting EEG:

- Anesthetic agents:

There are characteristic changes in EEG occurring in anesthesia.

- Light anesthesia:

EEG activation i.e. EEG shifts toward high frequency and low amplitude waves.

- With increased depth of anesthesia:

EEG depression i.e. EEG shifts toward low frequency with progressive increase in amplitude.

+ Burst suppression i.e. periods of isoelectricity in-between periods of activity.

- With more progressive increased depth of anesthesia:

There are periods of isoelectricity and finally an isoelectric line occurs.

2- Physiologic Factors:

- 1- Hypoxia; - Early → EEG activation i.e.
- Late → EEG depression i.e.
- 2- Hypercapnia; - Mild → EEG activation i.e.
- Marked → EEG depression
- 3- Hypocapnia → EEG depression.....
- 4- Hypothermia → EEG depression.....
- 5- Sensory stimulation → EEG activation

Indications (Clinical Uses) of EEG During Anesthesia:

1- Detection of Cerebral Ischemia :

- E.g. During; • Carotid endarterectomy • Head injury
- Cardiopulmonary bypass • Hypotensive anesthesia
- Neurosurgery • Drug toxicity
- EEG depression occurs when CBF reaches $< 15-20 \text{ mL/ min/100gm}$ of brain tissues.
- With more decrease of CBF, progressive depression occurs up to isoelectric line.
- Other factors can also cause EEG depression (as above) so, it is not specific.

2- Monitoring Depth of Anesthesia:

- Especially by • Power spectral analysis (spectral edge frequency or median frequency, both have moderate accuracy).
- Bi-spectral index; it provides a valid predictor.
- Effect of anesthesia on EEG..... as above.

3- Titration of Cerebral Protective Agents:

- To achieve the best cerebral protection by detecting burst suppression or isoelectricity

III- Evoked Potentials

It is non invasive assessment of neuronal function by measuring the electro-physiological responses of the CNS to a series of specific, repetitive sensory or motor stimuli.

The Response (Evoked Potentials)

The waveform formed of voltage versus time shows (figure 5-23);

Latency: It is the time in milliseconds from the onset of the stimulus to occurrence of a peak or time from one peak to another (inter-peak latency).

It is subdivided according to different latencies to;

- **Short latency potentials** (due to brain stem or nerve origin).
 - Its latency = $< 10 \text{ ms}$
 - It is the least affected by the anesthetic agents so it is used generally to detect ischemia of nervous tissues.
- **Middle latency potentials** (due to early cortical origin).
 - Its latency = $10 - 100 \text{ ms}$.
 - It is less affected, but still sensitive to the anesthetic agents.
- **Long latency potentials** (due to late cortical origin).

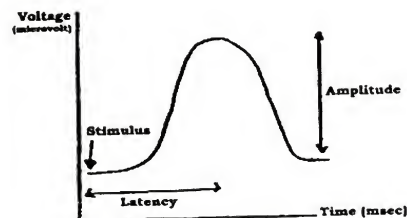


Figure 5-23; Waveform of evoked potentials

MONITORING DURING ANESTHESIA

- Its latency or conduction time is long i.e. potentials are recorded after the stimulus by **> 100 ms**.

- It is suppressed by anesthesia. Therefore, it is of limited value in intraoperative monitoring of ischemia.

Types (According to The Stimulus):

1- Visual Evoked Potentials

- They are produced by repeated flashes of light.

- They are the most sensitive of all other types to the effects of anesthetic agents, So, they are the least useful for intraoperative monitoring.

- They are used in surgeries involving optic nerve & chiasma, pituitary gland and thalamic tract.

2- Auditory Evoked Potentials (AEPs)

- **Stimulus:** By repeated clicking noise (by ear transducer) (figure 5-24).

- They are used in;

• Measuring the **depth of anesthesia** of different anesthetic agents by the **middle (early cortical) potentials** which are the **most promising** because they are the **most sensitive to the effects of anesthetic agents** as both volatile and i.v agents cause a dose-related increase in latency.

• Monitoring of brain stem function by **short latency (brain stem) AEPs** in:

- Comatosed patients.

- Surgeries of posterior fossa and brain stem e.g. cerebellar tumor, cerebro-pontine angle, acoustic neuroma.....

- Severe head injury.

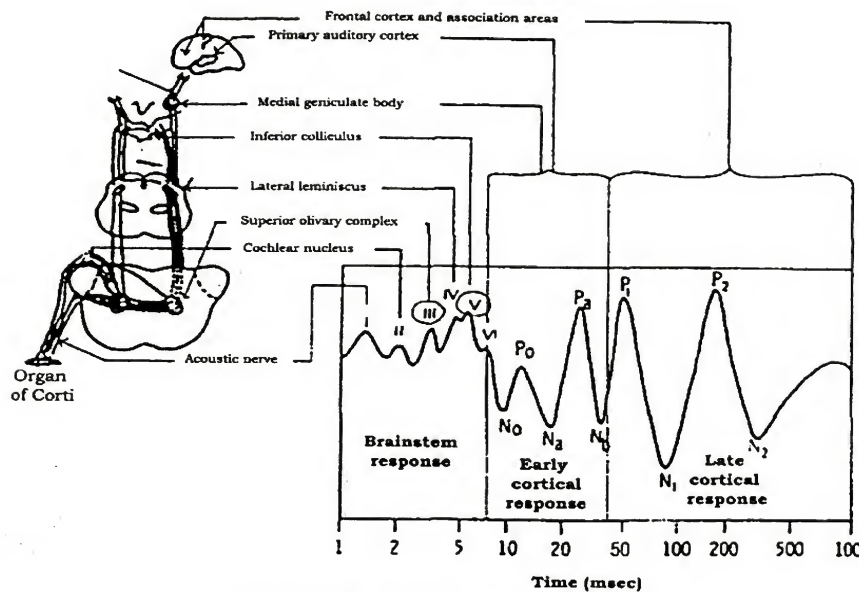


Figure 5-24; Auditory evoked potentials

3- Somato-Sensory Evoked Potentials (SSEPs)

- **Stimulus:** By electric stimulation over a peripheral nerve (e.g. posterior tibial, median nerve) giving 100-200 ms duration of 1-2 Hz frequency.

- **Response:** is detected by electrodes at various levels (along the neuro-sensory pathway) from the level of the cortex, epidural space or at the peripheral nerves themselves.

- Clinical Uses:

- a- **To assess spinal cord ischemia** as it monitors **dorsal column** of the spinal cord as in;
 - Scoliosis and corrective spinal surgeries.
 - Thoraco-abdominal and abdominal aortic surgery.
- b- **To assess cerebral ischemia** in;
 - Carotid endarterectomy surgery.
 - Head injury.
 - Craniotomy.
- c- **To assess peripheral nerve ischemia** in;
 - Brachial plexus exploration after injury.
 - Spinal disc surgery to monitor spinal roots.
- d- **To localize structures in the brain** as;
 - Lesions in the thalamus for Parkinson's disease
 - Lesions for pain syndromes.

- Factor Affecting SSEPs:**1- Ischemia:**

- Mild ischemia causes decreased amplitude > 50% &/or increased latency > 10 %.
- Severe ischemia causes complete loss of waveform.

2- Anesthesia:

- Local anesthetics: (via spinal or epidural) cause loss of SSEPs.
- Volatile agents: causes decreased amplitude and increased latency in dose-dependent manner.

The short latency SSEPs (specific) are the most commonly used intraoperatively to detect ischemia as they are less affected by anesthetic agents.

To obtain the best results during SSEPs monitoring;

- Keep **anesthesia stable before and during** the period of monitoring.
- Use **TIVA better than inhalational** anesthesia.
- Avoid use of **halothane > 0.5 %** and **isoflurane and enflurane > 1 %** if they are used.

3- Physiologic Factors:

- 1- Hypothermia causes increased latency \pm decreased amplitude.
- 2- Hyperthermia causes decreased amplitude.
- 3- Hypocarbica (ET CO₂ < 25 mm Hg) causes increased latency.
- 4- Hypoxia causes decreased amplitude.
- 5- Hematocrit: Hct < 15 % causes increased latency.
Hct < 7 % causes decreased amplitude.

4- Motor Evoked Potentials (MEPs)

- By electrical stimulation (by **direct electrical current or indirect via a magnetic field**) applied to the motor pathway at various levels from the motor cortex (trans-cranial, epidural "electrospinogram" down to the peripheral nerve itself. **Recently, trans-cranial multi-pulse electrical MEPs are used. They are less affected by anesthetic agents.**
- It is more sensitive than SSEPs to a reduction of spinal cord blood flow and correlates better with postoperative motor function because MEPs monitors the **motor pathway in the anterior column of spinal cord** which is more vulnerable to the effects of ischemia.

IV- Cerebral Blood Flow Measurement**1-Kety-Schmidt Method:**

- By application of Fick's principle which states;

MONITORING DURING ANESTHESIA

In a steady state, the amount of a substance taken by an organ / unit time = arterio-venous difference of the substance concentration across the organ x blood flow rate to that organ.

15% N₂O inhalation (for 10-15 min) is used and blood samples are taken every minute intermittently from a peripheral artery and jugular venous bulb.

2-Intracarotid Injection Method:

- It involves injection of a radioactive tracer (⁸⁵ Krypton or ¹³³ Xenon) as a bolus into the carotid artery. Cerebral washout can be measured by external scintillation counters. The sensitivity of this method can be improved by increasing the number of detectors. It allows measurement of **global and regional CBF**.

- No recirculation, because the tracer used (⁸⁵ Krypton or ¹³³ Xenon) is more soluble in air than in blood. They are almost completely exhaled on passage through the lungs.

3- Inhalational Method:

- It involves a 1- minute period inhalation of ¹³³ Xenon followed by a 10- minute period of washout and external detection.

4- Trans-Cranial Doppler:

- It measures blood flow velocity in the major vessels at the base of the brain via temporal bones. It is not useful in 20% of patients who are with temporal bone hyperostosis.

- Clinical uses:

1- Carotid endarterectomy.

2- Cardiopulmonary bypass (CPB).

• It is a sensitive indicator of carotid emboli during CPB.

5- Distal Stump Pressure:

See later anesthesia for vascular surgery.

V- Monitoring Depth of Anesthesia**A - Clinical Monitoring:**

1- **Movement:** (If muscle relaxants are not used).

- E.g. Reflex withdrawal in response to painful stimulus.

2- **Autonomic Responses i.e. Sympathetic Over-activity:**

- As increased HR, ABP, and pupil size dilatation, lacrimation and sweating.

3- **Change in Respiratory Rate in Spontaneously Breathing Patients.**

4- **Isolated Forearm Technique:**

- It is used for detection of intraoperative awareness.

- As one arm is isolated from the remainder of the circulation by inflation of a tourniquet on the upper arm before injection of muscle relaxant into the systemic circulation so, awareness can be detected by responding of the patient to the verbal commands of the anesthetists e.g. squeeze my hand.

All the clinical monitors are unreliable.

B- Electro-physiologic Monitoring:

Are used as adjuvant to the clinical monitoring.

1- **EEG-Unprocessed and Processed** "see before".

2- **Middle Latency AEPs**..... "see before".

3- **Spontaneous Facial (Frontalis Muscle) Electromyogram:**

- Anesthesia decreases the power of electromyogram reading from the frontalis muscle.

4- Spontaneous Lower Esophageal Contractility (SLEC)

- The spontaneous rhythmic activity of smooth muscles in the lower 1/3 of the esophagus is decreased in a dose-related manner by halothane, isoflurane and propofol (as it is a smooth muscle so, not affected by muscle relaxants).

N.B.; The usage of esophageal route as a monitor;

- Esophageal stethoscope.
- TEE.
- Esophageal temperature probe.
- Gastric tonometry.
- Spontaneous lower esophageal contractility to assess the depth of anesthesia.
- Esophageal lead of ECG.

5- Respiratory Sinus Arrhythmia:

- **Decreased respiratory sinus arrhythmia indicates increased depth of anesthesia**

(As no single method is considered enough for monitoring the depth of anesthesia, it is still a matter of art to detect the depth of anesthesia and titrate the doses of anesthetic drugs).

Monitoring of Metabolism

It includes;

- 1- Temperature monitoring.
- 2- Tissue oxygenation monitoring.
- 3- Indirect Calorimetry.
- 4- Fluid and electrolyte status monitoring
 - Measurement of blood loss....."see before"
 - Measurement of serum electrolytes....."see physics"
- 5- Blood gases and acid base status monitoring....."see before"
- 6- Hormonal status monitoring.
 - The metabolic response to anesthesia and surgery consists of
 - Increased catabolic hormones as cortisol, catecholamines.
 - Decreased anabolic hormones as insulin.

Temperature Monitoring

It must be applied for patients who are at risk of hypothermia as;

- Surgeries > 15 min
- Pediatric patients.

Value:

- **Core temperature** includes brain, thoracic and abdominal organs and some deep tissues of the limbs.

- **Shell temperature** includes a layer with a variable depth around 2.5cm.

- Average patient temperature

$$= 0.66 \times \text{Core temperature} + 0.34 \times \text{Average skin temperature.}$$

- Humans are homoeothermic, normal average = $37 \pm 0.5^{\circ}\text{C}$ with slight variations

- Units used;

1- Systemic International Units (SI) is **Kelvin (K)**

$$\text{K} = \text{Temperature in Celsius scale } (^{\circ}\text{C}) + 273.15$$

$$\text{So, zero K} = -273.15^{\circ}\text{C}$$

Not used clinically.

2- Celsius scale = $5/9 (F - 32)$

3- Fahrenheit scale = $9/5 \times (1/^{\circ}\text{C} + 32)$

MONITORING DURING ANESTHESIA**Clinical value:**

- 1- To detect **unintentional** hypothermia....."see anesthesia complications".
- 2- To control **elective** hypothermia....."see anesthesia for cardiac and neurosurgery".
- 3- To detect **hyperthermia** e.g. malignant hyperthermia.
- 4- To assess **peripheral perfusion**....."see cardiovascular monitoring".

Q: Discuss anesthesia and temperature changes?

Q: Discuss anesthesia and Hypothermia?

Techniques:**- Types of Thermometer:**

- 1- Thermistor.
- 2- Thermocouple.

Sites for Temperature Monitoring**A) Core Temperature by****1- Tympanic membrane:**

- It indicates core temperature (especially **brain** temperature)
- It is not routinely used due to risk of **perforation of the drum**.

2- Naso-pharyngeal:

- It indicates core temperature (especially **brain** temperature).
- There is a risk of **epistaxis**.

3- Esophagus:

- It indicates core temperature (especially **cardiac** temperature).
- **It is the best**, because it is safe and cheap.

4- Rectal:

- There is risk of **rectal perforation** (very rare).

5- Pulmonary artery catheter.**6- Urinary bladder.****B) Shell (Peripheral) Temperature by****1- Axially probe.****2- Skin by liquid crystal adhesive strips (e.g. great toe).**

N.B.; Oral temperature; It is used in the awake patients.

Neuromuscular Monitoring

I- Clinical Tests

It includes;

- 1- Ability to cough or swallow.
- 2- Sustained eye opening for at least 5 seconds (without diplopia).
- 3- Sustained head or leg lift for at least 5 seconds (without support).
- 4- Sustained protrusion of the tongue (without fade).
- 5- Sustained forceful hand grip (without fade).
- 6- Ability to resist removal of a tongue blade from clenched teeth (the most recent and the most sensitive clinical test).

+ Tests can be assessed in unconscious patients

- Inspiratory force to produce 25 cm H₂O (airway pressure).
- Vital capacity.
- Tidal volume.

Disadvantages:

- 1- It needs patient cooperation so; it is not suitable for unconscious patients (except the last three tests above).

2- They are insensitive tests:

When the clinical tests become adequate, train of four (TOF) ratio is 0.8 i.e. inadequate TOF ratios so; there is a **period of risk between appearance of clinical tests and adequate reversal of muscle relaxant**.

II- Peripheral Nerve Stimulation

Indications:

A- All patients **receiving muscle relaxants** due to the presence of variation in patient sensitivity to neuromuscular blockade. It is especially indicated in;

1- **Prolonged anesthesia** when;

- Intermediate or long acting muscle relaxants are given.
- Repeated doses or infusion of short acting muscle relaxants are given.

2- Presence of **neuromuscular diseases**.

3- Presence of **renal or hepatic diseases**.

4- Patient with history of **sensitivity** to muscle relaxants or poor recovery from them.

5- When **poor reversal** of NM block is encountered **unexpectedly**.

B- **During regional anesthesia** to;

- **Locate the nerves** to be blocked.
- Determine the **extent of sensory block**.

Technique:

Stimulus:

Applied by either;

- Subcutaneous **needle electrodes**.

Or - ECG silver chloride surface **electrodes**.

Current Amplitude:

Supra-maximal stimulus is needed i.e. the strength of the electrical stimulus should be increased until the response no longer increases (i.e. reaching the maximal stimulus). Then it is increased by a further 25% i.e. supra-maximal stimulus. This supra-maximal stimulus is to ensure consistent excitation of all muscle fibers despite minor variations of skin resistance over time.

Stimulus Site:

Stimulating electrodes (needle or surface), both -ve and +ve electrodes (especially -ve electrode) should be placed **over the course of the nerve tested** to avoid;

- Stimulation of another nerve which causes distorting assessment.
- Direct stimulation of the muscle which underestimates the degree of the block.

So, it can assess NMJ and not the muscle itself.

The Nerve Selected:

1- **Ulnar nerve stimulation:** (and monitoring adductor pollicis "thumb" muscle).

- It is the most commonly used (figure 5-25).
- One electrode is placed on the radial side of the flexor carpi ulnaris tendon about 1 cm proximal to the wrist skin crease. The other electrode is placed 3-4 cm

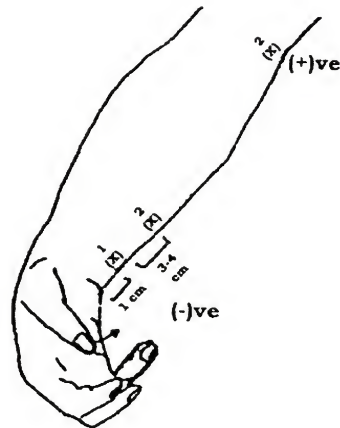


Figure 5-25; Ulnar nerve stimulation

MONITORING DURING ANESTHESIA

proximally, or over the ulnar groove on the medial epicondyle of the elbow. So, this arrangement causes stimulation of the flexor carpi ulnaris muscle it also augments thumb adduction.

- **Advantages of ulnar nerve stimulation:**

1. **Accessibility** of the ulnar nerve during operations.
2. The site of stimulation is on the medial site while the response is on the lateral site so, this **avoids direct muscle stimulation**.

2- **Facial nerve stimulation.**

3- **Posterior tibial nerve stimulation.**

4- **Peroneal and lateral popliteal nerves.**

Mode of Stimulation

1- Single Twitch (ST):

- Its duration 0.2 m sec can be repeated every 10 sec i.e. 0.1 Hz frequency (figure 5-26).

N.B.; Frequency = cycle / sec = Hertz

- It is of **limited value** because:

1. It is **insensitive** because;
 - It does not decrease until 75-80% of the receptors are blocked.
 - It disappears completely when 90-98% of receptors are blocked.
2. It is **difficult to assess** its fade or its comparison with subsequent twitches by visual or tactile means so; it needs to be measured by more sophisticated means (see later).

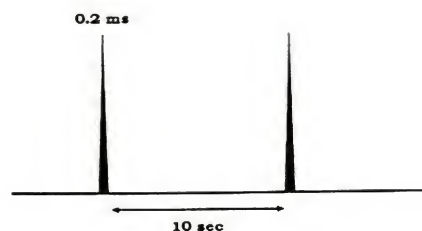


Figure 5-26; Single twitch

2- Train of Four Twitches (TOF): by Ali, Ulting & Gray 1971

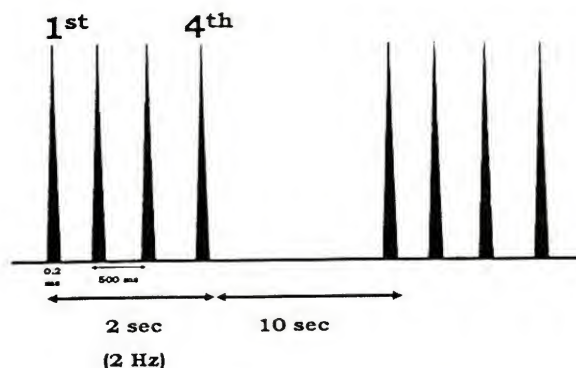


Figure 5-27; Train of four twitches

- It consists of a series of 4 twitches in 2 seconds i.e. 2-Hz frequency. Each twitch is 0.2 m sec duration. 10-second gap between each TOF is present. It is considered the **standard method** (figure 5-27).

- The ratio of the 4th to the 1st twitch i.e. T4/T1 ratio or **TOF ratio** can indicate presence of fade (i.e. gradual decrease in response on repeated stimulus) which occurs in phase II block of depolarizing muscle relaxants and the block of non-depolarizing muscle relaxants.

- **The degree of fade** is proportional to the extent of the NM block as follows:

- At the **unblocked NMJ** —————→ **TOF ratio = 1.0**
- During **phase I** block of depolarizing muscle relaxants, the twitch's height is decreased to the same extent in all four twitches i.e. no fade —————→ **TOF ratio = 1.0**
- During **phase II** block of depolarizing muscle relaxants or block of **non-depolarizing** muscle relaxants, T4 height start to decrease when 70-75% of receptors are blocked while

T1 is not decreased i.e. there is fade so, **T4/T1 ratio is decreased** (= 0.7). This can not be assessed by visual or tactile means.

- **With more increase of strength of the block:**

- 4th twitch disappears first.

Then, • 3rd twitch disappears.

Then, • 2nd twitch disappears.

Then, • 1st twitch disappears lastly.

Clinical relaxation occurs when 75-95% of receptors are blocked.

- **On recovery from NMJ block** the 1st twitch appears first then the 2nd then the 3rd and finally the 4th twitch appears.

- **Value of TOF:**

1. To obtain upper abdominal **muscle relaxation** for surgical access, at least the 4th, 3rd and 2nd twitches should be absent i.e. > 90% of receptors are blocked.

2. To **reverse** residual block of non-depolarizing muscle relaxants by anticholinesterase at least the 2nd twitch should be visible i.e. < 90% of receptors are blocked.

3. To **assess muscle tone** by clinical tests after reversal of muscle relaxant. At least TOF ratio should be 0.7 i.e. 70-75% of receptors are blocked at which clinical tests can be used as a good indicator for good muscle tone.

4. TOF is **less painful** than tetanic stimulation so, used to detect residual block in awake patient in recovery room and ICU.

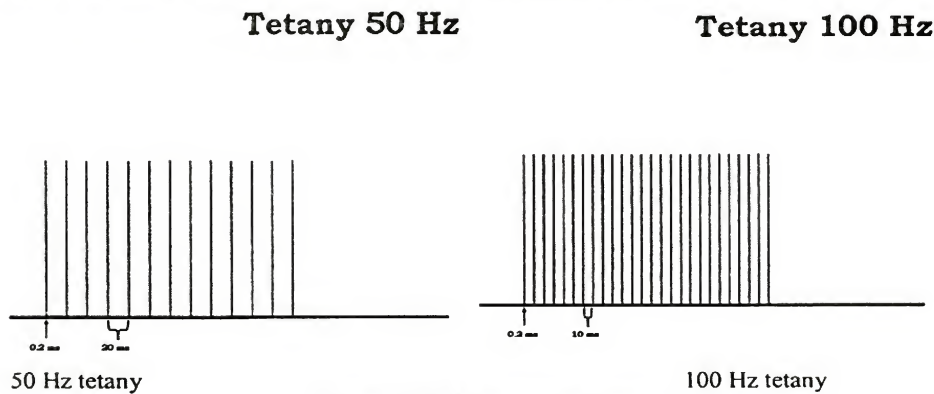
3- Tetanic Stimulation:

- It consists of sustained stimulus of 50-100 Hz usually lasting 5 seconds (figure 5-28).

- Detecting of **tetanic fade** is the **most sensitive mode** for detection of block of non-depolarizing muscle relaxants.

N.B.; In general, the higher the frequency of stimulation, the greater the sensitivity of the test i.e. 100 Hz tetany > 50 Hz tetany or TOF > single twitch 0.1 Hz.

- It is **intolerable and painful** in awake patients so, only used in anesthetized patients.



4- Post-Tetanic Potentiation (or Facilitation)

It consists of a single twitch followed by a 5 sec delay then a burst of 50 Hz tetany for 5 sec (figure 5-29). The effect of a further twitch 3 sec later produces an enhanced effect (potentiation). This occurs with phase II block of depolarizing and block of non-depolarizing muscle relaxants.

- In presence of a profound block, repeated single twitches applied after the tetany until the response disappears can be counted. This is known as **the post-tetanic count** which is inversely proportionate to the degree of the block i.e. increased post-tetanic count indicates low degree of block.

- As with tetany mode, it is **painful** in awake patients so, only used in anesthetized patients.

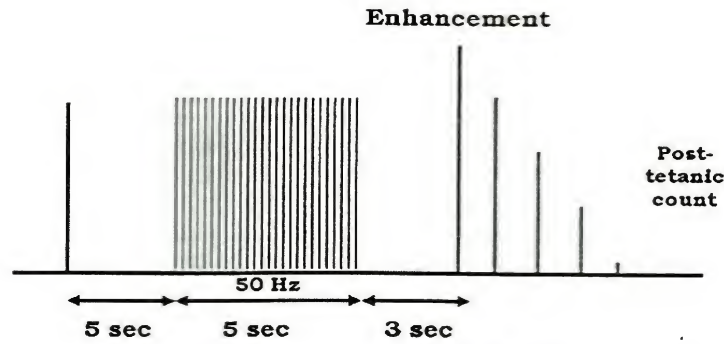


Figure 5-29; Post-tetanic potentiation

5- Double Burst Stimulation (DBS) by viby-Magensen

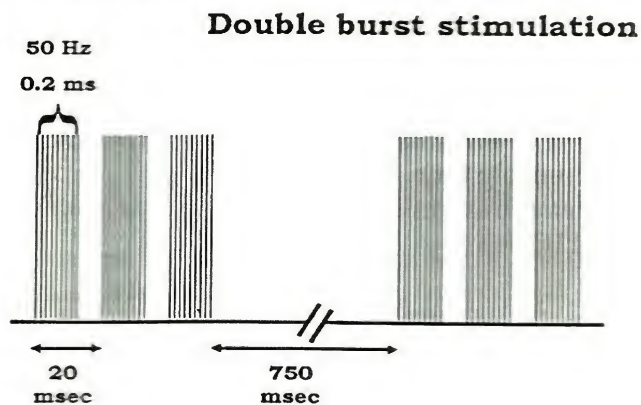


Figure 5-30; Double burst stimulation

- It consists of 2 mini-tetanic bursts of stimuli, the first mini-tetanic burst is formed of 3 impulses each impulse is 0.2 m sec and delivered at 50 Hz frequency and separated from next impulse by 20 m sec interval. The 2 mini-tetany bursts are separated by 750 m sec. The 2nd mini-tetany burst consists of 2 (DBS_{3,2}) or 3 (DBS_{3,3}) impulses (figure 5-30).
- The ratio of 2nd burst height (amplitude) to the first burst height i.e. D2/D1 ratio can indicate presence of fade as T4/T1 ratio.
- D2/D1 ratio has the same sensitivity as T4/T1 ratio if assessed by mechano-myography, but **D2/D1 ratio (fade) is more sensitive (and obvious)** than T4/T1 ratio (and fade) if assessed by visual or tactile means.
- It is better **tolerated** in awake patients (than tetany) because:
 - It is of short duration.
 - Using sub-maximal current stimulus (10-15 mA) without affecting its accuracy.

CHAPTER 6

ANESTHESIA FOR OBSTETRIC SURGERY

Two important notes must be always in mind:

- 1- The **physiologic changes** during pregnancy which can change the usual response to anesthesia.
- 2- Anesthetic care should be for 2 patients simultaneously (**the parturient and the fetus**).

Physiologic Aspects

Physiologic Changes During Pregnancy:

1. C.N.S:

Progressive decrease in MAC (for all GA agents) down to 40% at term is observed due to;

- Increased progesterone which has a sedating effect.
- Increased (a surge of) β endorphin during labor.

So, a pregnant female is subjected to loss of consciousness even by a small concentration of inhalational anesthetics (less than the non-pregnant). This causes loss of protective upper airway reflexes which easily allows aspiration.

2. Respiratory System:

1- Respiratory center is stimulated by progesterone therefore,

- **Increased minute volume** about 50% occurs.

It is one of the earliest changes. So, induction and emergence from anesthesia is faster than in the non pregnant females.

- Increased tidal volume, respiratory rate, and PaO_2 occur with decreased PaCO_2 and HCO_3^- by the same level so, the pH remains 7.4

2- Elevation of the diaphragm by the pregnant uterus therefore,

- Decreased chest and lung compliance about 40% occur.
- Decreased ERV and RV occurs resulting in decreased FRC.

3- Hypoxemia is common due to:

- Increased O_2 consumption about 20%.
- Decreased FRC so, the closing volume exceeds FRC in 50% of pregnant females in the supine position causing atelectasis. Therefore, rapid O_2 desaturation during the period of apnea is common. So, Preoxygenation prior to induction of GA is mandatory.

4- Dead space:

- The anatomical dead space is unchanged except in late pregnancy, where it is decreased due to upper airway edema.
- The physiologic dead space is increased about 40%.

So, dead space / tidal volume ratio is unchanged (as both are increased equally).

5- Oxy-Hb dissociation curve:

- It is shifted to the right (i.e. P_{50} is increased from 27 to 30 mm Hg). This increases O_2 delivery to tissues due to increased RBCs 2,3 di-phosphoglycerate.

ANESTHESIA FOR OBSTETRIC SURGERY**6- Engorgement of the respiratory mucosa:**

- This easily allows upper airway trauma, bleeding and obstruction. So, gentle laryngoscopy, use of small ETT (6.5-7 mm) and gentle suction are recommended.
- N.B.; Excessive hyperventilation due to unrelieved pain, mechanical or manual ventilation decreases $\text{PaCO}_2 < 20$ mm Hg. This causes;
 - VC of utero-placental vessels which decreases utero-placental blood flow.
 - Respiratory alkalosis which shifts Hb dissociation curve to the left and decreases O_2 delivery.
- Both cause fetal hypoxia which produces fetal acidosis and bradycardia.

3. C.V.S:

A state of **hyperdynamic** circulation occurs.

1- Increased HR 15%, stroke volume 30%, and CO 45% is observed.

- During labor, CO doubles due to expulsive force at 2nd stage.
 - In the immediate post-delivery period, CO increases further due to auto-transfusion.
- These are the most dangerous times for mothers with cardiac disease or pre-eclampsia, so regional anesthesia may protect these patients.

2- Vasodilator effect of progesterone causes;

1. Decreased systemic vascular resistance 20% therefore, diastolic BP is decreased 20 %, but little change in systolic BP occurs due to increased blood volume and CO.
2. Decreased pulmonary vascular resistance 34%, but no change in pulmonary artery pressure or PCWP occurs due to increased blood volume and CO.
3. Decreased tone in capacitant veins but no change in CVP due to increased blood volume and CO.

3. Decreased oncotic pressure:

- Because the increase in plasma volume is mainly due to H_2O rather than colloid component.

So, oncotic pressure - PCWP gradient is decreased significantly. Therefore, a pregnant female is more liable to develop pulmonary edema.

4. Aorto-caval compression (supine hypotension syndrome):

It occurs in 10-20 % of pregnant females, after 28 weeks of pregnancy.

a- Compression of the inferior vena cava (IVC):

- Compression of the IVC is done by the gravid uterus on lying supine which decreases VR. The latter decreases CO and BP causing stimulation of compensatory mechanisms as;
 - Sympathetic stimulation leading to VC and increased HR. This increases VR, CO and BP again.
 - Increased venous pressure below the level of IVC obstruction diverts venous blood from the lower ½ of the body via paravertebral venous plexus to the azygos vein which drains into the SVC and right heart. This increases VR, CO and BP again.
- If the compensatory mechanisms are enough, they maintain BP and no symptoms appear. This is called **concealed caval occlusion**.
- If the compensatory mechanisms are not enough (e.g., during GA or regional anesthesia), CO and BP decrease and symptoms as nausea, vomiting, dizziness, anxiety and fetal hypoxia (causing fetal acidosis and bradycardia) appear. This is called **revealed caval occlusion**.

b- Compression of the aorta:

- Compression of the aorta is done by the gravid uterus on lying supine. This decreases the BP to the lower ½ of the body causing decreased in utero-placental blood flow which in turn produces fetal hypoxia (causing fetal acidosis and bradycardia).

So, avoid the supine position after 28th week of pregnancy by:

1. Lateral uterine displacement (usually to the left side, >15 degree) by;
 - Rotating the delivery table to the left.

- Placing a pillow or wedge under the right side of the back and buttock.

2. I.v. fluids.

3. I.v. ephedrine (if hypotension occurs).

5. Increased venous pressure in the lower limbs increases liability to phlebitis, edema and varicose veins.

4. Hematologic Changes:

Increased blood volume 40% to reach 85-90 mL/kg at term.

- Due to increased plasma volume 45%
and increased RBCs volume 20%

This causes a dilutional effect (**maximal 32 week of pregnancy**) which results in **physiologic anemia of pregnancy** (i.e. decreased Hb to 12 gm % and Hct to 36%)

This allows the pregnant woman to control blood loss during vaginal delivery (400-500 mL) and C.S (800-1000 mL).

5. Renal Changes:

1. Increased RBF and GFR 50 % is apparent at 10-15th week of gestation.
2. Decreased s. creatinine to 0.5-0.6 mg % (50%) and BUN to 8-9 mg % (50%) occur.

6. Hepatic Changes:

1. No change occurs in hepatic blood flow or hepatic function i.e., AST and ALT .
2. Increased s. alkaline phosphatase occurs because it is secreted from the placenta.
3. Decreased total proteins and s. albumin occur, due to increased plasma volume (dilutional effect).
4. Decreased s. pseudo-cholinesterase by 30% occurs, but clinically, it does not affect suxamethonium, mivacurium or the ester type of LA action.

7. GIT:

- **Increased gastro-esophageal reflux** occurs which increases esophagitis, risk of regurgitation and aspiration because;
 1. Upward displacement of the stomach by the uterus causing;
 - Incompetent gastro-esophageal physiological sphincter.
 - Increased intragastric pressure > lower esophageal sphincter pressure.
 2. Progesterone decreases gastric motility and tone of gastro-esophageal sphincter.
 3. Placental gastrin increases gastric acidity (gastric pH < 2.5 and gastric volume >25 mL).
 4. Narcotics and anticholinergics decrease gastro-esophageal sphincter tone.
 5. Labor pain and anxiety delay gastric emptying up to 18 hrs (gastric emptying is not delayed during pregnancy).

8. The Epidural and Subarachnoid Spaces Changes:

Decreased doses of LAs about 30-50 % (even in the 1st trimester) for both blocks are observed due to;

1. Decreased volume of both spaces. This causes more cephalad spread of LAs due to dilatation and engorgement of epidural veins by:
 - Progesterone effect.
 - Aorto-caval compression.
 - Increased intra-thoracic or intra-abdominal pressure by straining.
2. Progesterone-induced hyperventilation. This decreases PaCO₂ which results in increased renal compensatory HCO₃⁻ excretion. Therefore, HCO₃⁻ is decreased causing a decrease in buffering capacity. So, LA drugs remain as free salts for a longer time resulting in increased LAs action.

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3. Increased pressure in epidural space which facilitates diffusion of LAs across the dura. This increases LAs concentration in CSF.
4. Venous congestion at lateral foramina which decreases escape of LAs along the dural sleeves.
5. Exaggerated lumbar lordosis which may increase cephalad spread of LAs.

Utero-Placental Blood Flow (UBF)

At term UBF is $\approx 500 - 700 \text{ mL/min}$ (50 mL/min in non-pregnant females). (80 % to placenta and 20% to myometrium). It is 10% of CO.

- No autoregulation is present because during pregnancy uterine vessels are maximally dilated so, UBF is directly proportionate to uterine perfusion pressure (figure 6-1).

$$\text{UBF} = \frac{\text{Uterine perfusion pressure}}{\text{Uterine vascular resistance}}$$

$$= \frac{\text{Uterine arterial pressure} - \text{Uterine inter-villous pressure}}{\text{Intrinsic resistance of spiral arteries} + \text{Extrinsic resistance (myometrium tone)}}$$

$$= \frac{\text{Uterine arterial pressure} - (\text{Intrauterine pressure} + \text{uterine venous pressure})}{\text{Intrinsic resistance of spiral arteries} + \text{Extrinsic resistance (myometrium tone)}}$$

Spiral arteries have no smooth muscle so, they have low resistance.

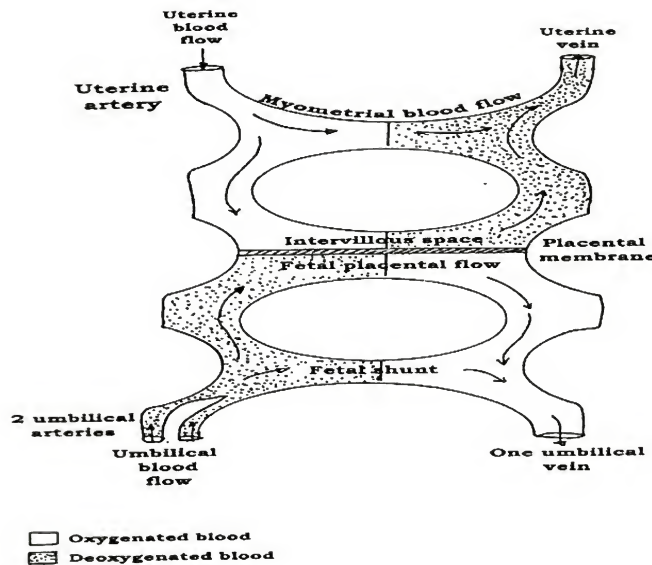


Figure 6-1; Utero-placental circulation

UBF is decreased by:

1. **Hypotension** due to;
 - Aorto-caval compression.
 - Hypovolemia (hemorrhage).
 - Sympathetic blockade due to regional anesthesia.
 2. **Uterine artery vasoconstriction** due to;
 - Stress-induced release of endogenous catecholamines during labor.
 - Drugs with α adrenergic activity e.g. phenylephrine.
- N.B.; Ephedrine is mainly with β adrenergic activity so, it is of choice in hypotension with pregnancy.

- Hypertension and pre-eclampsia.
- Extreme hypocapnia e.g. $\text{PaCO}_2 < 20$ mm Hg.

3. Uterine contractions due to;

- During labor.
- During oxytocin infusions.

The normal fetus can tolerate 50% reduction in UBF because there is good circulatory reserve. If UBF is decreased more, fetal hypoxia occurs which in turn produces fetal acidosis (it is used to test adequacy of UBF) and bradycardia.

Effect of Anesthetic Agents on UBF:

1. **Volatile anesthetics** decreases maternal BP which decreases UBF.

2. **I.v. anesthetics** as;

- Barbiturates and propofol decrease maternal BP which decreases UBF.
- Ketamine produces no effect because its VC effect is compensated by its increased BP effect.

3. **Local anesthetics** especially lidocaine, if unintentional i.v. injection occurs, uterine VC is produced producing decreased UBF.

N.B.; - Spinal and epidural anesthesia have no effect on UBF provided that hypotension is avoided.

- Epidural anesthesia in pre-eclampsia actually increases UBF because it decreases pain and stress which decreases endogenous catecholamines.
- Addition of epinephrine to LAs has no effect on UBF.

Effect of Labor on Maternal Physiology:

During intense uterine contractions, there is an increase in the following, over 3rd trimester values.

- Minute volume is increased 300% which decreases PaCO_2 less than 20 mm Hg.
- O_2 consumption is increased 60%.
- CO is increased 45%.

Immediately, in the post-delivery period, when intense uterine contractions suddenly stop, relief of I.V.C. obstruction (auto transfusion) occurs causing increase in CO up to 80%, so, this is the most dangerous time for mothers with cardiac disease or preeclampsia.

Physiology of Pain in Labor:

Sequence of pain in labor:

Unrelieved pain causes sympathetic stimulation which;

- Increases CO, BP, and delays gastric emptying.
- Decreases UBF due to;
 - Increased plasma cortisol and catecholamines.
 - Hyperventilation which produces hypocapnia. Therefore, respiratory alkalosis occurs producing fetal hypoxia (i.e. acidosis and bradycardia).

1ST stage: uterine contraction and cervical dilatation. It needs block of T10-L1

2nd stage: delivery of the baby distortion. There is stretch and tearing of perineal and vaginal fibers. It needs block of S 2,3, and 4.

3rd stage: delivery of the placenta. It is painless stage.

Effects of Anesthetic Agents On Uterine Activity & Labor

1. Inhalational Anesthetics:

They produce dose dependent uterine relaxation (< 0.5 MAC has no effect).

ANESTHESIA FOR OBSTETRIC SURGERY**2. Regional Anesthesia:**

a. **Direct effects:** On toxic doses, tetanic contractions are produced.

b. **Indirect effects:**

1. **Prolongation of labor:**

- **Early in 1st stage:** regional anesthesia is suggested to prolong the early course of labor, but this is very difficult to be confirmed. Actually, it abolishes stress and pain- induced release of endogenous catecholamines which can inhibit coordinated and effective uterine contractions so, it can enhance early progress of labor.
- **2nd stage of labor** can be prolonged because regional anesthesia removes the reflex urge of the parturient to bear down.

2. **It increases the incidence of mid-forceps deliveries** (controversy) due to:

- It removes the reflex urge of the parturient to bear down in 2nd stage.
- It abolishes a reflex increase in endogenous oxytocin from distention of the lower birth canal (Ferguson reflex).
- Relaxation of pelvic musculature interferes with flexion and internal rotation of the fetus which may predispose to persistent occiput posterior presentation.

So, all of these effects can be avoided by;

- Using low concentration of LAs for epidural anesthesia to preserve skeletal muscle functions.

Or - Withholding perineal doses of the LAs until descent and rotation of the fetus have occurred.

3. **Effect of fluid loading with the start of epidural block:**

Fluid load decreases endogenous oxytocin secretion from the pituitary (the same as fluid loading decreasing endogenous ADH). This decreases uterine activity transiently.

3. Vasopressors:

- α_1 receptors cause uterine contractions e.g. phenylephrine, methoxamine.
- β_2 receptors cause uterine relaxations e.g. epinephrine-containing LAs.

4. Others:

- Magnesium depresses uterine contraction.
- Oxytocin induces and increases uterine contraction.
- Methergine increases duration and power of uterine contraction.

Analgesia for Vaginal Delivery

General considerations for all pregnant females in labor:

1- Pre-anesthetic history and examinations are done because pregnant females are liable for anesthesia.

2- An 18-gauge or larger i.v. cannula is inserted.

3- Keep NPO, give i.v. fluids as lactated ringer or dextrose with 0.45% saline to prevent dehydration.

N.B.; Ketosis may occur with labor and is not necessary related to the degree of dehydration.

4- Blood samples are sent for typing and screening.

A- Non-Pharmacologic Methods:

1- Psychological Methods:

- E.g. - Breathing technique (Lamaz technique): a deep breath at the beginning of each contraction followed by rapid shallow breathing for duration of each contraction
- Presence of the father.

- 2- Hypnosis.
- 3- Acupuncture.
- 4- **Decompression suit**: applied to the abdomen. It facilitates labor because it produces good analgesia and shortens the 1st stage.
- 5- **Trans-cutaneous nerve stimulation**.
- 6- **Electro-analgesia**.

B- Pharmacologic Methods:

I- Parental Drugs:

1. Narcotics:

- Disadvantages:
 - Maternal: Respiratory depression and delaying gastric emptying.
 - Fetal: CNS, respiratory depression, acidosis, abnormal neurobehavioral examinations, and loss of beat to beat variability (as cross placement).
 - It is easily reversed by naloxone 10 µg/Kg into the umbilical cord vein.
- E.g.: • Pethidine:
 - The most commonly used, i.v. or i.m. or patient controlled analgesia.
 - Maximum respiratory depression in neonates occurs after 3 hrs (i.m) and 10-20 min (i.v.) so, avoid it within 2 hrs of delivery and inform pediatric staff.
 - Morphine, fentanyl, pentazocineetc.

2. Ketamine:

- Analgesic dose 0.25 mg/kg i.v.
- It has no effect on UBF, uterine activity and neonatal status at this dose.

3. Thiopentone: may cause loss of consciousness.

4. Phenothiazines: e.g. promethazine.

5. Diazepam:

- Dose: 5-10 mg i.v.
- On larger doses > 30 mg, floppy infant syndrome occurs which is characterized by (hypotonia, lethargy, poor feeding, hypothermia, and respiratory distress).

II- Inhalational Analgesia:

1. Entonox:

- It is the most commonly used in the U.K.
 - It is a premixed N₂O: O₂ (1:1), stored in a gaseous phase in cylinders kept above- 7°C.
- Advantages:

- It allows **high inspired O₂** concentration.
- It is **self-administrated**.
- N₂O at that concentration produces **no physiologic or biochemical effects**.

2. Sub-Anesthetic Doses of Volatile Agents:

- E.g. Halothane (< 0.5%), isoflurane (< 1%) + N₂O at these concentrations allow analgesic action without loss of airway reflexes.

III- Local Anesthetic Techniques:

- General considerations:

1. **History, explanation, and consent.**
2. Adequate equipment for **resuscitation** should be present + available **anesthetists**.
3. Satisfactory **i.v. line** before start.

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4. Avoid aorto-caval compression by **left lateral position**.
5. Measure **ABP /5 minutes** and more frequently if hypotension occurs.
6. **Monitor fetal heart rate** continuously.
7. Sensory block level required:
 - During the **1st stage**: to block labor pain of uterine contractions → **T₁₀ – L₁**
 - During the **2nd stage**: to block perineal pain → **extend to S₁ – S₅**
 - If C.S. is planned → **extend to T₂ – T₄**

Lumbar Epidural	-----	T ₂₋₄
& Subarachnoid Block		<u>C.S.</u>
Caudal Block	-----	T ₁₀
Para-cervical Nerve Block	<u>1st stage</u>	L ₁
Saddle	Pudendal Nerve Block	<u>2nd Stage</u>
	-----	S ₁₋₅

1. Para-cervical Nerve Block:

- **Indications:** It produces block at the level of T₁₀ L₁ so, it is used in the **1st stage** only.
Technique: usually done by obstetricians LA is injected **into each fornix of the vagina lateral to the cervix** (at 3.0 clock and 9.0 O'clock). it is not used in the **2nd stage**.

- Disadvantages:

1- The site of injection is very close to the **uterine arteries** causing VC which in turn decreases utero-placental blood flow.

2- High vascularity is present in the para-cervical area causing **increased systemic absorption**, therefore, more LAs are transferred to the fetus producing high fetal blood levels of LAs which cause fetal cardiac toxicity.

So, **fetal hypoxia, bradycardia and acidosis** can occur 2-10 minutes after injections.
 So, it is rarely used nowadays and if used.

2. Pudendal Nerve Block:

- **Indications:** It produces block at the level of S₂ – S₄ so, used in the **2nd stage** of labor e.g. episiotomy, outlet forceps, and repair of lacerations.

1. **Technique:** Usually done by obstetricians just before delivery while the patient is in lithotomy position LA is injected **above and behind the palpated ischial spine** on each side.

3. Caudal Block:

- **Indications:** It produces block at the level of T₁₀-S₅ so, it is used during the **1st and 2nd stages**.

- **Technique:**See local anesthesia for technique.

- Spreading of the drug and so, the level of the block is less predictable.

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- Technically more difficult due to exaggerated lumbar lordosis that accompanies pregnancy.

- **Continuous spinal analgesia** by 28 gauge micro-catheter is tried, but it may cause cauda equina syndrome.

6. Combined Spinal-Epidural Analgesia:

- **Advantages:** It has the combined value of:

- **Rapid onset** of spinal block so, it can be used in late labor.

- The ability of **extending the block** of the epidural catheter so, it can be used in early labor.

- **Technique:** by;

- **Needle-through needle technique:**

Epidural needle 17-gauge is 1st inserted in the epidural space then a longer spinal needle 25-27 gauge needle is inserted through the epidural needle and advanced into the subarachnoid space until CSF is obtained the spinal needle must protrude 12 mm at least beyond the tip of the epidural needle.

After intrathecal injections of sufentanil 2.5-10 µg or fentanyl 10-25 µg, the spinal needle is withdrawn and an epidural catheter is passed.

The epidural catheter is then tested by a test dose of LAs to avoid subarachnoid position by the test dose.

- **Needle- beside-needle technique:**

It employs a specially designed epidural needle that has a channel for the spinal needle.

- In the past, it was done by **2 separate needles introduced in 2 separate spaces.**

- **Disadvantages:**

1. It has the disadvantages of both the spinal and epidural block, but the actual incidence of post-dural puncture headache is less than with epidural alone because the spinal needle may be used to verify the correct position of the epidural needle when loss of resistance is not sure.

2. Subarachnoid spread of epidurally administered drugs produces higher level of block.

3. Subarachnoid migration of the epidural catheter (very rare).

N.B.; Epidural or Intrathecal Opioid Alone:**Advantages:**

1. **No sympathetic block** so, **no hypotension** thus, it is useful in patients with hypovolemia, aortic stenosis, pulmonary hypertension, and right-to-left shunts.

2. **No motor block** so it preserves the ability of the mother to **push during 2nd stage** but there is lack of perineal relaxations.

3. **Weak sensory block** so, mothers can feel contractions and know when to push but it causes weak analgesia.

4. **No LAs toxicity.**

Disadvantages:

"see opioid pharmacology".

Pharmacokinetics and doses:

"See opioid pharmacology".

N.B.; Patient controlled Epidural Analgesia (PCEA)

- **Advantages:** (Over continuous epidural infusion)

It provides better matching between drug dose and patients need as;

- Less local anesthetic consumption.

- Less maternal motor blockade.

- Better maternal pain relief (as evidenced by a less provider delivered boluses).

- Mechanism:

Bolus injection (by PCEA) may produce more extensive spreading of drugs than continuous infusion. Pump-administered bolus doses produce greater injection pressure which makes drug exits from all holes of the multi-holed catheter while with continuous infusion, drug exits almost exclusively from the most proximal hole. Therefore, PCEA produces better analgesia with less drug than continuous epidural infusion.

- Dosage (PCEA setting):

- Basal rate: 4 mL/hr.
- Bolus : 5 mL.
- Lockout : 5 min.
- Limit : 24 mL/hr.

- Combined spinal-epidural technique is used either;

- **Intrathecal injection** (3 mL of 3.75 mg ropivacaine + 1.5 µg sufentanil).

+ **Epidural infusion** "start PCEA immediately after intrathecal injection" (0.125 % ropivacaine + 0.5 µg/mL sufentanil).

Or • **Intrathecal injection** (2 mL of 2-2.5 mg bupivacaine + 3-4 µg fentanyl).

+ **Epidural infusion** "start PCEA immediately after intrathecal injection" (0.1-0.125 % bupivacaine + 2 µg/mL fentanyl).

Q : What are the new techniques for labor analgesia ?

- 1- Walking (mobile) epidural anesthesia.
- 2- Continuous spinal analgesia.
- 3- Combined spinal-epidural analgesia.
- 4- Epidural or spinal opioid alone.
- 5- Continuous epidural analgesia (LA + opioids).
- 6- Patient controlled epidural analgesia.

IV- General Anesthesia:**- Indication:** in vaginal delivery only when:

1. There is a need for **uterine relaxation** e.g. intrauterine manipulation, version and extraction, manual removal of retained placenta, replacement of inverted uterus, and breach extraction.
2. There are contraindications to regional anesthesia and other methods are inadequate.
3. If acute fetal distress occurs during 2nd stage of labor and operative vaginal delivery is indicated.

- Techniques:

- Place a wedge under right hip for **left uterine displacement**.
- **Preoxygenation** for 3-5 minutes while applying a monitor to the patient.
- **Rapid sequence crush induction with cricoid pressure and intubation** (as all pregnant women are at risk of aspiration).
- **Awake extubation**.

Anesthesia for Cesarean Section (CS)**I) Regional Anesthesia:****- Advantages:**

1. It **avoids** the risk of **aspiration** of gastric contents.
2. **Blood loss** is usually **halved** (compared to CS with GA).
3. It **avoids neonatal** depression by GA drugs especially a compromised fetus.
4. It allows **early maternal-infant bonding & breast feeding**.

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5. It allows **postoperative analgesia** by using spinal opioids.

- A suggested technique:

Regional anesthesia is applied to achieve **T₄ – S₅ block** by either:

- Lumbar epidural anesthesia.
- Lumbar subarachnoid (spinal).
- Combined spinal-epidural anesthesia.

A) Lumbar Epidural Block:

- **Advantages:**

- Advantages of regional anesthesia.
- + - Opposite to disadvantages of spinal block.

- **Disadvantages:**

1. Time consuming and **delayed onset** (45 min versus 10 min in spinal) so, unsuitable for emergency C.S.
 2. **More LAs** are used therefore, there is increased risk of toxicity and fetal effects.
 3. Relatively **more difficult** than spinal block without positive end point i.e. CSF detection in subarachnoid block.
 4. **More patient discomfort** during performance of the block.
- A suggested technique: as above + "see local anesthesia".

- **Agents:**

- Bupivacaine, 10-15 mL 0.5%, produces complete anesthesia within 45 min.
- Top up doses are then given using bupivacaine 0.5% 1.5 mL/segment needed to be blocked (about 5-7 mL) up to T₄ level block.

B) Subarachnoid (Spinal, Intrathecal) Block:

- **Advantages:**

- Advantages of regional anesthesia;
- + Opposite to disadvantages of epidural block. "See above".

- **Disadvantages:**

- 1) **Hypotension:** is more severe and more common than with epidural block.
- 2) **Postoperative headache.**
- 3) **Level of anesthesia is less controllable.**
- 4) **No postoperative analgesia.**

As no possibility of top up doses except if using continuous spinal anesthesia by micro-catheters (under trials).

- **A Suggested Technique:** as "above + see local anesthesia".

- **Agents:** dose is chosen according to patient's height.

- If she is < 155 cm so, give 1.8 mL hyperbaric bupivacaine.
- If she is 155- 170 cm so, give 2.2 mL hyperbaric bupivacaine.
- If she is > 170 cm so, give 2.6 mL hyperbaric bupivacaine.

II) General Anesthesia:

- **Indications:**

1. **In emergency C.S.**

E.g. • Peri-mortem C.S.

- Fetal distress.
- Expected hemorrhage in placenta previa (without epidural catheter inserted before).

2. **Contraindications for regional anesthesia** e.g. patient refusal, back sepsis, coagulopathy.

- A suggested technique:

- Preoperative visit and explanation.
 - Premedications:
 - Antacids (in emergency CS) or H₂ antihistaminic (in elective surgery).
 - Metoclopramide.
 - Glycopyrrolate (instead of atropine) as anticholinergic and antisialagogue.
 - Left uterine displacement by a wedge under the right hip.
 - Preoxygenation with 100% O₂ for 3-5 min while monitors are applied in emergency CS. Adequate O₂ can be achieved rapidly by 4 maximal breaths with 100% O₂.
 - The patient is prepared and draped for surgery.
 - When the surgeons are ready, **rapid-sequence crush induction with cricoid pressure** is performed by skilled assistant as soon as consciousness is lost by:
 - Thiopentone 5-7 mg/kg (larger dose to decrease awareness) replaced by ketamine 1 mg/kg in hypovolemic patients.
 - Succinylcholine 1.5 mg/kg.
 - Surgery is begun only after proper placement of cuffed ETT size 7.0-7.5.
 - Maintenance by:
 - N₂O: O₂ (5:5).
 - A low concentration of volatile agents up to (halothane 0.5% - isoflurane 0.75% - enflurane 1%) is used. This low concentration ensures amnesia without producing excessive uterine relaxation.
 - Short or intermediate muscle relaxant is used e.g. atracurium or vecuronium and mechanical ventilation is adjusted to achieve ET CO₂ of 30 mm Hg.
 - After delivery of the baby:
 - The inspired O₂ can be decreased to N₂O: O₂ (6: 4).
 - I.v. opioid is given while continuing the volatile agent at appropriate concentration to decrease risk of awareness.
 - Oxytocin infusion 10-20 IU/Liter.
- If the uterus does not contract readily so,
- Stop volatile agents and increase N₂O: O₂ (7: 3) while giving opioids.
 - Methergine 0.2 mg i.m/iv is given.
 - An attempt to aspirate gastric content can be made by an oral gastric tube to decrease the risk of aspiration on emergence.
 - Monitor blood loss, cross-matched blood should be available but rarely used.
 - On emergence:
 - Reverse muscle relaxants.
 - Remove gastric tube if used.
 - Awake extubation.

Q: Discuss the anesthetic managements of emergency C.S.?

- A: Discuss;*
- General anesthesia instead of epidural anesthesia.
 - Risk of anesthesia of C.S. is increased e.g. failed intubation, aspiration..
 - Causes of emergency C.S. e.g. eclampsia, rupture uterus, fetal distress.

Q: Discuss the anesthetic managements of high risk C.S.?

- A: Discuss;*
- Risk of anesthesia of C.S. is increased e.g. failed intubation, aspiration..
 - Complicated C.S.

Risks of Anesthesia for C.S.

Especially with emergency C.S.

I) Difficult (Failed) Intubation:

- **Incidence** in obstetric patients 1:300
- Causes of increased incidence in obstetric patients.
- Laryngeal and airway edema especially in PIH.

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• Large breasts which obstruct the laryngoscope handle especially in short neck patients.

Risks:

- Rapid occurrence of severe hypoxia may cause arrest.
- Increased risk of regurgitation and vomiting which may cause aspiration.

Precautions Before Attempting Intubation:

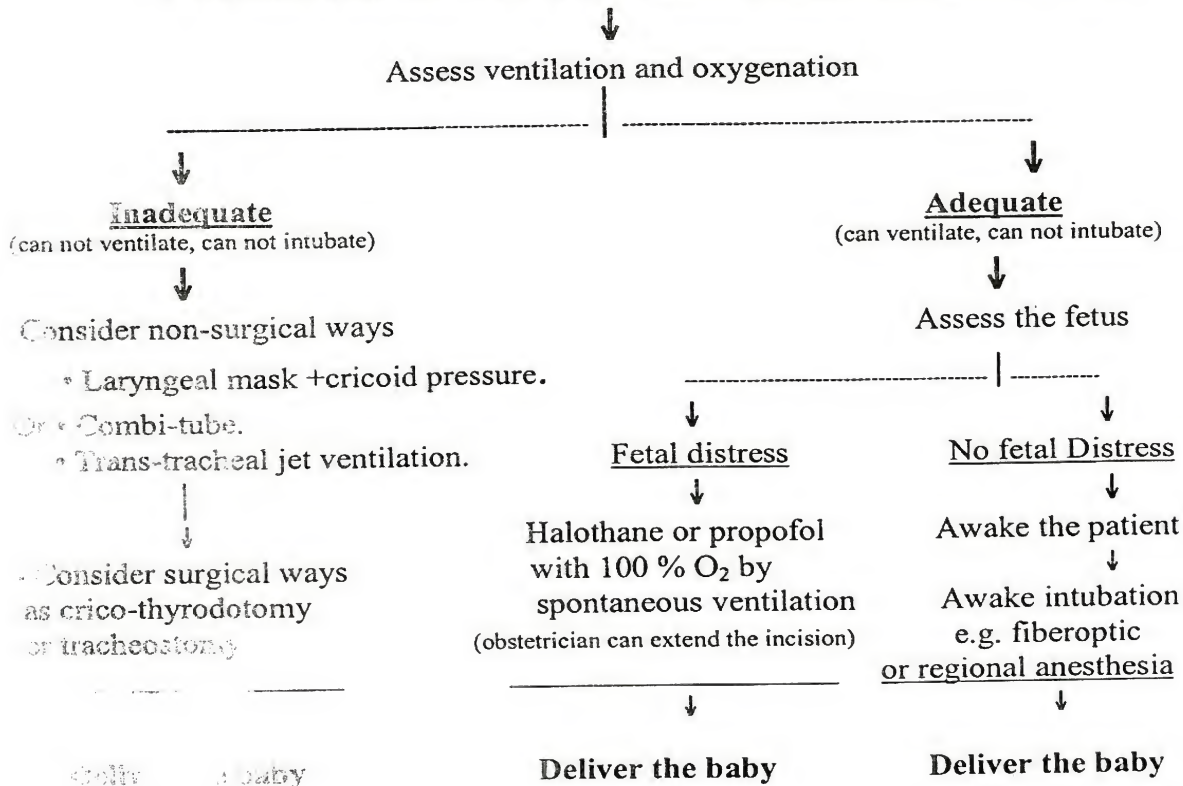
1. Pre-anesthetic assessment. "See airway management".
2. Obtain optimal laryngoscopic intubation attempt.
3. All equipments required for difficult intubation should be available as;
 - A 2nd laryngoscope with different blade size.
 - Different tube sizes, Magill forceps, oral, nasal airways, and laryngeal masks.
 - Introducers, stylets, bougies.
 - Esophageal obturator, combi-tube.
 - Fiberoptic bronchoscope.
 - Cricothyroid puncture set and i.v. cannula, mini-tracheostomy set.

Failed Intubation Drill:

Early decision to enter the protocol of failed intubation drill is very important

Failed Intubation

- 1- Call for senior help to obtain optimal attempts.
- 2- Put the patient on the left side with the head down.
- 3- Cricoid pressure.
- 4- Ventilate with 100 % O₂ by (face mask, laryngeal mask, comb-tube).



II) Inhalation of Gastric Contents:

- **Incidence** in obstetric patients **1:500**

Causes of increased incidence in obstetric patients. "See maternal physiology"

- **Risks:** Aspiration pneumonia especially if gastric pH is < 2.5, and the gastric volume > 25 mL.

- **Prevention:**

1. **Decrease gastric volume by:**

• **NPO** (Nill per os) during labor.

• **Large gastric tube** which withdrawn before induction.

• **Drugs:** they do not decrease the already present gastric volume.

- **Metoclopramide** 10 mg i.v/i.m 1-2 hrs before induction.

- **Cimetidine** 300 mg i.v/i.m 1-2 hrs before induction.

- **Ranitidine** 50 mg i.v or 150 mg i.m 1-2 hrs before induction.

2. **Decrease gastric acidity by:**

• **Antacids**, to neutralize the existing acids, but they increase the gastric volume as 0.3 M solution of sodium citrate 15-30 mL orally, 15-30 min before induction.

N.B.; Non-particulate antacids (Na citrate or Na bicarbonate) are better than particulate antacids (aluminum or Mg hydroxide) as the later mixes poorly with gastric content and if aspirated, it produces pneumonitis.

• **H₂ receptor antagonists**; increase the pH up to 5, but do not affect the already existing pH. E.g.- Cimetidine.

- Ranitidine.

3. **Prevention of regurgitation by:**

• **Increasing lower esophageal sphincter tone by:**

- Metoclopramide.

- Avoiding diazepam, opioids, atropine.

• **Avoid increased intragastric pressure by:**

- Avoid positive pressure ventilation before intubation.

- De-fasciculation by a non-depolarizing muscle relaxant, but recently suxamethonium protects against aspiration and regurgitation.

4. **Prevention of inhalation** (if regurgitation occurs) by:

• **Cricoid pressure** (sellik's maneuver), the most important.

• **Rapid sequence (crush) induction** in lateral position.

• **Powerful suction.**

• **Cuffed ETT.**

5. **Be aware of difficult intubation.**

6. **Prefer regional anesthesia.**

7. **Awake extubation.**

- **Diagnosis and Management of Aspiration:** "See anesthetic problems"

III) Awareness During GA:

- **Incidence** in obstetric patients **2-26%.**

Causes of increased incidence in obstetric patients include;

The use of low doses of anesthetic drugs especially before delivery of baby.

- **Risks:** It may be auditory, tactile ± appreciation of pain.

• **Intraoperative sympathetic stimulation** decreases utero-placental blood flow.

• **Postoperative psychic trauma and dreams.**

- **Prevention:** measures to avoid awareness:

1. Adding **halothane 0.5 %** to N₂O: O₂ (5: 5) **before delivery.**

and adding **opioids** and increasing N₂O: O₂ (6: 4) immediately **after** cord clamping.

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2. An initially high concentration of inspired volatile agent (2-3 MAC) as soon as intubation has been achieved until the end-expired concentration approximates 1 MAC detected by **volatile agent analyzer**.
3. An induction dose of **thiopentone** 5-6 mg/kg.
4. **Isolated forearm technique**. "See CNS monitoring".

IV) Effect of Anesthesia on The Fetus:

1. Hazard of Maternal Hyperventilation:

- Due to either: - Unrelieved pain.
 - Mechanical or manual ventilation.
- Both produce hypocapnia and respiratory alkalosis.

As - Hypocapnia causes VC of utero-placental vessels resulting in decreased UBF.

- Respiratory alkalosis causes O₂-Hb dissociation curve shift to the left resulting in decreased O₂ delivery to the baby.

Both causes fetal hypoxia and acidosis.

2. Hazard of Anesthetic Drugs:

- Barbiturates decrease maternal BP which decreases UBF.
- Volatiles decrease maternal BP which decreases UBF.
- Local anesthetics especially i.v lidocaine cause uterine VC which decreases UBF.
- Ketamine has no effect.

3. Induction Delivery Interval:

- During GA, the concentration of anesthetic drugs increase progressively in fetal circulation so, on prolonged induction delivery interval neonatal depression may occur.
- The optimal induction delivery time is **10-20 min (up to 30 min)**.
- The **uterine delivery interval** (time from uterine incision to delivery) is more important.
- After **90 sec**, fetal asphxia and acidosis begin due to;
 - Partial placental separation.
 - Impaired placenta blood flow.
 - Premature fetal respiratory efforts cause aspiration of liquor.

N.B.; The urgent nature of obstetric operations added to certain obstetric complications (e.g. PIH, breech presentation, fetal distress), both adds to the risk of GA in obstetrics and emergency CS.

Anesthesia for High Risk (Complicated) **Obstetrics**

I) Pregnancy Induced Hypertension (PIH) **(Toxemia of Pregnancy) Pre-eclampsia & Eclampsia**

Definition: according to the American Obstetric Committee.

- **Pre-eclampsia:** occurs after the 20th week of pregnancy (2nd half) and it is triad of;
 - **Hypertension:** ABP \geq 40/90 or mean BP > 105 mm Hg.

Increase systolic > 30 mm Hg above the baseline.

Or Increase diastolic > 15 mm Hg above the baseline.

Or Increase mean BP > 20 mm Hg above the baseline (in superimposed PIH).

- **Proteinuria** > 500 mg/day.
- **Generalized edema.**

- **Eclampsia:** occurs pre-, intra- or postpartum (up to 48 hrs). It is a severe form of the disease **with** generalized grand mal **convulsions** associated with 10% maternal mortality due to congestive heart failure or intracerebral hemorrhage.

Classification of Hypertension With Pregnancy

by American College of Obstetricians & Gynecologists.

1. Pregnancy induced hypertension (PIH): incidence is 6-8 % of pregnant females.
 - Pre-eclampsia and eclampsia.
 - Gestational hypertension.
2. Coincidental hypertension: chronic hypertension preceding pregnancy.
3. Chronic hypertension with superimposed PIH.

Degrees of Pre-eclampsia:

	Mild	Moderate	Severe
C/P: 1. ABP 2. Edema 3. Reflexes 4. Visual signs	140/95 mild normal ---	150-160/ 100-110 moderate hyper-reflexia + early	>160/110 severe hyper-reflexia ++ marked + congestive heart failure. + fits with eclampsia.
Investigations 1. BUN mg % 2. S. Creatinine mg % 3. Urate mg % 4. Proteinuria gm/day 5. Thrombocytopenia	< 10 < 1 < 4.5 0.5 --	10-20 1-1.6 4.5-6 0.5-2 mild	> 20 > 1.6 > 6 > 2 severe

HELLP Syndrome

- It is a **severe** form of preeclampsia which may occur ante- or postpartum.
- It consists of:
 1. Hemolysis:
 - Peripheral blood smear shows micro-angiopathic hemolytic anemia with burr cells (crenated, distorted RBCs with spiny projections along the periphery), schistocytes (small irregular shaped RBCs fragments), and polychromasia.
 - There is normal PT, PTT, fibrinogen in 96 % of patients.
 2. Elevated Liver enzymes:
 - Increased SGOT, SGPT, bilirubin (especially indirect).
 - Also increased BUN and s. creatinine in 50 % of cases.
 3. Low Platelet count ($< 100\,000/\text{mm}^3$)
 - C/P: malaise, nausea, and epigastric pain. Edema and hypertension may be absent. There is increased risk of complications as DIC, placenta abruption, pleural effusion, acute renal failure and wound infection.
 - Once diagnosed,
 - Rapid delivery is indicated.
 - Platelet transfusion (if $< 20\,000/\text{mm}^3$).
 - Packed RBCs (if with postpartum hemorrhage).

Etiology:

Heterogeneous causes of both maternal and placental origin.

Due to Immunological Factors: (mostly).

- By • Contents of seminal fluids as **spermatozoa** may produce antibody formation or PGs that cause uterine vasoconstriction.
- Or • Abnormal maternal fetal Ag-Ab reaction as **the fetus** has 50 % of his genom from the father.

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- In pre-eclampsia, by unknown cause (mostly immunological).
 - **Prostacyclin (PGI₂) and NO deficiency** in mother and feto-maternal tissues.
 - **Thromboxane A₂ (TxA₂) overproduction** in the placenta.
- Both cause VC and increased platelet activity.
- Increased TxA₂ and decreased PGI₂ and NO cause increased platelet aggregation, VC, decreased UBF causing uterine ischemia. This causes
 - Release of **thrombo-plastic materials** which are deposited in renal glomeruli producing **proteinuria**.
 - Release of **uterine renin** which stimulates angiotensin system causing VC and **hypertension and edema**.

Patho-Physiologic Changes (Complications) in Different Organs:

(VC and hyper-excitability)

1. Hematologic Changes:

- Decreased blood volume especially plasma resulting in hemo-concentration and relative anemia.
- DIC.

2. Cerebral Changes:

- Increased CNS irritability causing **hyper-reflexia up to fits** in eclampsia.
- Increased ICP exaggerated by hypoxia, hypercapnia and acidosis.
- In severe cases **coma** occurs without eclampsia.
- **Cerebral hemorrhage** (30-40% of causes of death in PIH).

3. Respiratory Changes:

- Upper airway and laryngeal edema.
- **LVF and pulmonary edema**.
- O₂-Hb dissociation curve is **shifted to the left** decreasing O₂ delivery to the fetus.

4. C.V.S Changes: VC causes;

- **Hypertension**.
- **LVF and pulmonary edema**.

5. Ophthalmic Changes: VC causes;

- Retinal artery spasm.
- In severe cases bilateral **retinal detachment** causing blindness due to retinal edema.

6. Renal Changes: VC decreases renal blood flow which results in;

- Damaged glomeruli, with consequent decreased **GFR** (oliguric renal failure) and **proteinuria**.

7. Hepatic Changes:

- **Hepato-cellular damage** resulting in increased liver enzymes.
- **Sub-capsular hematoma** or liver rupture.
- **Hemolysis** producing jaundice.
- **HELLP syndrome**.

8. Utero-placental Changes:

- Uterus: - **Hyperactive** painful contractions.
 - Increased sensitivity to oxytocin.
 - **Couvainr uterus**.
- Placenta: - **Premature aging and infarctions**.
 - **fibrin** and calcification deposits.
 - **Abruption**.
- Fetus: - **Premature labor** is common.
 - **Intrauterine growth retardation** or small for gestational age so, there is

increased incidence of respiratory distress, aspiration of meconium and increased sensitivity to depression by anesthetic drugs.

Treatment of PIH:

The definitive treatment is **delivery of the fetus and placenta**. The disease resolves within 48 hours after delivery.

1. **Improve oxygenation** by supplying O₂.

2. **Improve circulation** to vital organs as the uterus, placenta and kidney by;
- Keeping the patient in the **left lateral position** to avoid aorto-caval syndrome.
 - **Antihypertensive drugs** if diastolic BP > 110 mm Hg.

The aim: to reach a BP of 150/100 and not less, to allow adequate perfusion.

- E.g.:
- Hydralazine (the most common).
 - Nitroglycerine.
 - Nitroprusside, yet on prolonged use, fetal cyanide toxicity may occur because the liver of the fetus is still immature so, it is better avoided.
 - Labetalol (the 2nd common).
 - Ca⁺⁺ channel blockers.

3. **Improve intravascular volume:** guided with CVP or UOP by;

- Isotonic crystalloids e.g. lactated ringer till UOP reaches 30 mL/hr.
- Colloids e.g. 5% albumin to correct the decreased colloidal pressure.
- Blood transfusions if hematocrit becomes < 27%.

N.B.; Avoid D₅W alone because:

- If oxytocin is added to i.v solution, water intoxication occurs causing convulsions due to antidiuretic action of oxytocin.
- If rapid infusion occurs, maternal hyperglycemia and neonatal hypoglycemia may be present

so, use 5% dextrose in 0.45 % NS (if needed) instead of D₅W alone.

4. **Improve cerebral edema** by; osmotic diuretics.

5. **Treatment of convulsions (eclamptic fit):**

- Prophylaxis: by Mg sulfate or diazepam.
- Treatment:
 - Maintain adequate airway, give O₂, turn patient to the left side with head down, up to intubation with succinylcholine and cricoid pressure.
 - I.v. thiopentone 50-100 mg immediately to terminate fits. Further fits are treated with diazepam or Mg sulfate.
 - AB gases and pH are done because HCO₃⁻ may be needed as fits usually cause metabolic acidosis.

Mg sulfate:

- **Action:**

1. It causes presynaptic inhibition of ACh release and decreases postsynaptic sensitivity to Ach. This produces;
 - CNS depression and anticonvulsant action.
 - NMJ: depression and decreased muscle membrane excitability.
2. It causes mild relaxant effect by direct and indirect action (Ca⁺⁺ competing). This produces;
 - Relaxation of the uterus and decreased uterine hyperactivity so, increased UBF occurs.
 - Mild vasodilatation and antihypertensive effects so, increased UBF, renal, and hepatic BF occurs.

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- **4 gm i.v** in 20 % solution over 5-20 min then continuous infusion **1-2 gm/hr**.
(in the past, infusion was replaced by 5 gm i.m in each buttock).
- Additional 2-4 gm can be given i.v. if fits persist.
- Continue infusion for 12-24 hrs postpartum or 24 hrs more after the last postpartum fits in eclampsia.

- **Normal plasma level** **1.5-2 mEq/L**

- **Therapeutic level** **4-6 mEq/ L**

- Judgment of therapeutic level

1. Deep tendon (knee) jerk: present, but hypoactive.
- Its absence indicates impending toxicity which occurs at 10 mEq/L.
2. Respiratory rate: > 10-12/min. If less, decrease or stop $MgSO_4$.
3. Urine output: > 30mL/hr. If less, decrease or stop $MgSO_4$.

- Precautions:

1. It **potentiates** both depolarizing and non-depolarizing **muscle relaxants** so, : - Nerve stimulator is essential.
- Use smaller doses of muscle relaxants.
- No need for defasciculation of succinylcholine as $MgSO_4$ attenuates fasciculation.
- PIH decreases plasma cholinesterase which potentiates suxamethonium (independent on $MgSO_4$ effect).
2. It **potentiates** both **narcotics and sedatives** so, use smaller doses of them.
3. It is excreted by the **kidney** so, it is used cautiously in patients with **renal diseases**.

- $MgSO_4$ toxicity: C/P:

- At 5-10 mEq/L → prolonged QT interval and wide QRS complex (ECG).
At 10 mEq/L → loss of deep tendon reflex.
At 15 mEq/L → SA node and AV node block (CVS) + **respiratory** paralysis.
At 25 mEq/L → cardiac arrest.

• **Avoidance:**

- Continuous clinical judgment of the therapeutic level (as above).
- Measure s. Mg /2hr.

• **Treatment:**

- Stop $MgSO_4$ immediately.
- Cardiac and respiratory resuscitation.
- Ca^{++} is the antidote, but given only in severe toxicity (not used routinely) because it antagonizes the anticonvulsant effect of $MgSO_4$.

Anesthetic Management

Monitoring: Standard monitoring +

- **Monitoring the therapeutic level of Mg^{++} .**
- Monitoring the circulatory volume state in severe cases CVP, PCWP.
- Monitoring of invasive intra-arterial line for invasive ABP in severe cases, and blood samples for arterial blood gases.
- **Monitoring obstetrics:**
 - Uterine contractions.
 - Fetal status by:- Cardio-scope for fetal heart sound.
- Fetal scalp pH.

Choice of Anesthesia:**1. Continuous Epidural Block:**

- It is of choice for pain relief during vaginal delivery or C.S provided that there is:

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- No circulatory volume depletion with proper control of hypotension.
- No coagulopathies.

- Advantages:

1. **It decreases the level of catecholamines** (which are secreted 2ry to anxiety and pain) and abolishes VC so, it allows better perfusion of utero-placental and renal vessels.
2. **It avoids the increase in ABP and ICP** with intubation and bearing down.
3. It has a **slow onset of sympathetic block and hypotension** (than in spinal block).
4. **It avoids using systemic narcotics** as in GA which depress respiration.

- Precautions:

- 1- **Pre-hydration** before performing the block.
- 2- **Coagulation study** before performing the block.
- 3- **Early insertion of epidural catheter** as labor tends to be rapid.
- 4- **Avoid epinephrine containing LAs** due to increased sensitivity of maternal vessels to catecholamines.
- 5- **Monitoring fetal HR** is essential to detect early fetal distress.

2. General Anesthesia:- Indications:

- Urgent C.S with distressed fetus.
- Epidural contraindications e.g. DIC.

- Technique: as before in CS except;

- Patient preparation includes **treatment of preeclampsia or eclampsia**.
- **Rapid smooth induction with smaller size tubes** (due to air way edema) by:
 - Thiopentone (ketamine is contraindicated).
 - Suxamethonium (no need for de-fasciculation as $MgSO_4$ attenuates it).
- **Avoid pressor response** to intubation by:
 - Lidocaine 100 mg i.v 3-5 minutes before induction.
 - Hydralazine, labetalol, nitroglycerine, trimethopran or nitroprusside with invasive BP monitoring.

- Maintenance with N_2O : O_2

+ volatile agents (2/3 of MAC): **Avoid nephro-toxic drugs e.g. methoxyflurane**

+ muscle relaxants: Careful titrate the dose by using a **nerve stimulator** due to $MgSO_4$ effect.

Avoid pancuronium.

- **Continue $MgSO_4$** intra- and postoperative.
- **Avoid ergometrine** except in very severe uterine atony as it increases ABP and eclampsia.
- Postoperatively:
 - Continue $MgSO_4$ up to 24 hrs in preeclampsia and 24 hrs after the last postpartum fit in eclampsia.
 - Continue anti-hypertensive drugs.
 - Continue i.v fluids.
 - Pain control.

II) Premature Labor (Preterm Labor)

- It is delivery between 20-37 weeks of gestation.

- Treatment of Premature Labor and Anesthetic Management:

1. Bed rest.
2. **Tocolytics:** To decrease uterine activity and inhibit preterm labor.

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E.g.: $MgSO_4$, Ca^{++} channel blockers, indomethacin, prostaglandins inhibitors.
 B_2 agonist e.g. Ritodrine (Yotepar), yohimbine (Gynapral), and terbutaline.

Side effects:

- **Tachycardia and arrhythmias** (by β_1 action) so, avoid atropine, pancuronium and take care with halothane.
- **Hypokalemia**, which increases muscle relaxant sensitivity and causes heart arrhythmias.
- **Hypertension** so, avoid ketamine.
- **Pulmonary edema** so, cautious pre-hydration is done.
- **Hyperglycemia** so, take care in diabetic patients.
- **Fetal tachycardia and hypoglycemia** so, careful resuscitation is done.

So, delay anesthesia for at least 3 hrs after stopping tocolytics to allow β_2 action to be dissipated.

3. If labor is still in progress, either vaginal delivery or CS is planned

Epidural or low spinal block is of choice (than GA) because:

1. It provides maximal analgesia e.g. for generous episiotomy or outlet forceps.
2. It provides maximal pelvic floor relaxation.
3. It avoids exposure of a relatively more sensitive premature fetus to CNS depressant anesthetic drugs or their systemic toxicity.

4. The risks of a premature baby:

- More susceptible to **asphyxia** as there is increased risk of umbilical cord compression.
- More susceptible to **IC hemorrhage** during vaginal delivery due to soft cranium.
- More susceptible to **idiopathic respiratory distress syndrome** due to inadequate surfactant which reaches adequate level after 35 weeks of gestation.

So, prepare for complete fetal resuscitation before delivery.

III) Maternal Hemorrhage During Labor:

A- Antepartum Hemorrhage:

Causes:

1- **Abruptio placenta**; i.e. premature separation of the placenta:

It causes **painful vaginal bleeding**, concealed hemorrhage, and DIC.

2- **Uterine rupture**:

It causes **severe abdominal pain**, shock, and disappearance of fetal heart rate.

3- **Placenta previa**; i.e. encroachment upon internal cervical os:

It causes **painless vaginal bleeding**.

Diagnosis of placenta previa:

Any ante-partum vaginal bleeding is considered placenta previa until proved otherwise by:

1. **Abdominal U/S** to localize the placenta.
2. **Double setup examination of the patient**: i.e. the parturient is placed in lithotomy position for vaginal examination in the operative room with every thing prepared for immediate C.S. as her abdomen is prepared and draped + anti-hemorrhage measures are prepared.

- Management:

a- Severity of hemorrhage is estimated by:

Patient's vital signs, Hct, CVP, external blood loss (but it may not be related to the degree of shock).

b- Before vaginal examination:

- Blood volume should be restored before examination (in emergency situations, O -ve packed RBCs is given till blood typing is completed).
- Two large patent venous lines should be secured.
- Two units of blood should be available in the operative room.

c- If urgent CS or exploration for uterine rupture is indicated:

- GA is of choice with good preoxygenation and ketamine induction.
- Regional anesthesia is avoided because:
 - Not enough time as it is an emergency.
 - Possibility of DIC.
 - Hypotension is more common.

B- Intra-Partum Hemorrhage:

Uterine rupture is the most common cause more with vertical uterine incision than low transverse segment incision.

C- Post-Partum Hemorrhage:

- It is hemorrhage after delivery which exceeds 500 mL. It can occur within 6 weeks, but mostly shortly after delivery.

- Causes:

1. Uterine atony due to: prolonged 1st stage of labor, preeclampsia, multiple parity or births, large fetus or poly-hydramnios, or retained placenta.
2. Obstetric lacerations.
3. Retained placenta, incomplete empty of uterus or placenta accreta.
4. Uterine inversion.
5. Clotting defects.

- **Management:**

1. **Resuscitation** of shocked patients.....

2. **Treatment of the cause:**

• **Treatment of atony by:**

1- **Oxytocin** infusion up to 40 IU/L: It produces systemic vasodilatation so, rapid i.v. injection may cause hypotension.

2- **Methyl-ergonovine (Methergine)** 0.2 mg i.m/ i.v. infusion: It produces peripheral vasoconstriction so, rapid i.v. injection may cause acute hypertension, cerebro-vascular accident, pulmonary edema, and coronary vasospasm so, **avoid rapid i.v. injections.**

3- **PG analogue (F2 α) (Carboprost):** i.m. or directly into the myometrium 0.25 mg with maximum dose 1.5 mg: It produces bronchospasm and systemic and pulmonary vasoconstriction so, i.v. injection may cause severe bronchospasm, systemic and pulmonary hypertension.

• **Examination under anesthesia and repair of perineal laceration:**

3. **Emergency hysterectomy** very rare.

N.B.: Placenta accreta: abnormal adherence and invasion of placenta into the myometrium. It causes antepartum and postpartum hemorrhage. It is treated by hysterectomy.

IV) Maternal Heart Diseases:

Anesthetic Problems:

1. Many C.V.S. changes occurring with pregnancy can mimic those of cardiac diseases so, **careful differentiation** is required.

E.g.: Dyspnea, leg edema, heart murmurs, and cardio-megally in x-ray.

N.B.: Hepato-megally and congested neck veins do not occur during pregnancy.

2. During pregnancy and labor, **physiologic changes** can affect heart disease e.g. increased CO **precipitates congestive heart disease** in 50 % of patients with dyspnea with minimal activity.

3. **Drugs can cross placenta and affect the fetus.**

- Lidocaine causes fetal depression.
- Propranolol causes fetal bradycardia.
- Digitalis causes fetal toxicity.

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4. Preoperative **antibiotic prophylaxis** against endocarditis such as:

- Ampicillin 2 gm i.v/im + Gentamycin 1.5 gm/kg i.v/im are given 1 hr before labor, and continue during labor and 2 days after labor.

5. The patients are of 2 groups:

Disease	MR, AR, cardiomyopathy of pregnancy, dissecting aortic aneurysm, congenital heart disease with left to right shunt.	MS (90% of cases), AS, primary pulmonary hypertension, coarctation of the aorta, congenital heart disease with right to left shunt or bidirectional shunt.
Try aim	Avoid increased preload (VR) and afterload (systemic vascular resistance).	Avoid decreased preload (VR) and afterload (systemic vascular resistance).
Choice of Anesthesia	Continuous lumbar epidural block is preferred as it decreases the preload and afterload so, it decreases pulmonary congestion and edema.	GA is preferred Regional block is avoided and if it is necessary, use opioid alone.

V) Diabetes Mellitus With Pregnancy:Anesthetic Problems:

1- Maternal: Increased incidence of

- PIH.
- Diabetic ketoacidosis especially in the 2nd and 3rd trimester.
- Insulin is used as it does not cross the placenta (unlike oral hypoglycemics which cross the placenta and cause neonatal hypoglycemia).

2- Fetal: Increased incidence of

- Large baby size.
- Premature labor.
- Fetal hypoglycemia.
- Respiratory distress syndrome.
- Congenital diseases.

VI) Amniotic Fluid Embolism:

- Due to entry of amniotic fluid in to the maternal circulation.
- Patho-physiology and C/P:see Anesthesia with Respiratory Diseases.

VII) Ectopic Pregnancy:Anesthetic Problems:

1- Patients may be normovolemic with mild abdominal pain up to severely shocked with major internal hemorrhage.

2- Severe hemorrhage may occur intraoperatively.

So, - Cross matched blood should be available in the operating theater.

- At least one large bore i.v cannula should be inserted before induction.
- Rapid sequence induction after period of preoxygenation with the surgeon standing by, with ketamine or etomidate if hypovolemia is anticipated.
- Regular coagulation screens should be done as DIC may occur with severe hemorrhage.

Anesthesia For Non-Obstetric Surgery in Pregnant Patients

- Postpone all elective surgeries till 6 weeks after delivery and perform only emergency surgery during pregnancy especially in the 1st trimester.
- The most common surgeries are excision of an ovarian cyst, appendicectomy, cervical cerclage, trauma, breast mass biopsy.

+ Anesthesia might be applied in early undiagnosed pregnancy.

Anesthetic Problems:

1- Physiologic Changes of Pregnancy: "see maternal physiology"

Especially:

- Decreased local and inhaled anesthetic doses.
- Decreased functional residual capacity.
- Decreased gastric emptying so, there is an increased risk of regurgitation.
- Aorto-caval compression.

2- Teratogenicity of Anesthetic Drugs:

- Three periods of pregnancy can be affected:

a- **1st 15 days** post-conception:

- Effect of drugs are either **lethal** or **may have no effect**.

b- From **15-56 days** post-conception:

- It is the **period of organogenesis**, drug exposure may cause major developmental abnormalities.

c- **After 56 days** post-conception:

- It is the **period of organ growth** so, drug exposure may cause either growth retardation or minor morphological abnormalities.

- Generally, no documents are reported in human as regard teratogenicity of any anesthetic agents except:

- **N₂O**; much controversy is present because it produces:
 - Inhibition of methionine synthetase so, it affects **myelin** synthesis.
 - Inhibition of thymidylate synthetase so, it affects **DNA** synthesis.
 - **Increased sympathetic activity decreases UBP** which is prevented by addition of volatile agents.

- Teratogenic effects in animals during prolonged exposure (not in humans).

so, there must be **caution** during its use during pregnancy.

- **Benzodiazepines** are associated with **cleft lip** anomalies.

• In USA and UK, large retrospective studies suggest that female anesthesiologists and the wives of male anesthesiologists had an increased incidence of spontaneous abortion and congenital anomalies in babies than non-operating room physicians so, it is suggested that chronic exposure to trace anesthetic gases is the cause.

So, it is recommended that **time-tested anesthetics** e.g. halothane, morphine are used instead of new agents e.g. desflurane, remifentanyl.

3- Risk of Premature Labor Initiation:

- There is no evidence that a specific anesthetic agent or technique is associated with a higher or lower incidence of premature delivery, actually the underlying pathology necessitating the operative intervention is the affecting factor e.g. premature labor in patients undergoing a cervical cerclage.

4- Adequacy of Utero-Placental Perfusion: "see maternal physiology"

So, avoid hypotension, stress responses, extreme hypocapnia (by hyperventilation).

Anesthetic Management

- **Monitoring:** Standard +

• **Fetal heart rate** by doppler after 20-24 weeks of gestation to detect decelerations which indicate inadequate utero-placental circulation (N.B.; Loss of beat to beat variability is not indicative after anesthesia).

• **Uterine activity by computerized toco-dynamo-gram (CTG)** to detect premature labor as regular uterine activity necessitates early treatment with tocolytics.

Both should be done pre-, intra-, and postoperative up to all the recovery period.

ANESTHESIA FOR OBSTETRIC SURGERY**- Preoperative Assessment:** Standard +

- A pregnancy test should be in mind in all females in the child-bearing period.
- Premedications:

1- To prevent aspiration.....

2- Glycopyrrolate (does not cross the placenta) as an anticholinergic, and an antisialagogue.

3- Sedatives to decrease stress of the patients so, maternal catecholamines are decreased which in turn decrease UBF.

4- Tocolytics if regular uterine activity occurs.

- Choice of Anesthesia:**A-Regional Anesthesia:**

- It is preferred than GA although there is no evidence that GA has adverse effects.
- Spinal block is preferred than epidural block due to less doses of LA agents used.

B-GA:

The same precautions with CS +

- N₂O is controversy so, omit it or use a small concentration.
- Use time-tested agents e.g. halothane, morphine.
- Avoid ketamine > 2 mg/kg as it causes uterine hypertonicity.
- Slow reversal of muscle relaxants to prevent acute increase in Ach which may induce uterine contractions.

N.B; Appendicitis:

- The incidence of gangrenous appendix is increased during pregnancy because enlarged uterus pushes the appendix away from the abdominal wall causing little pain. Therefore, delayed diagnosis occurs.
- There is an increased incidence of pulmonary edema and ARDS if tocolytics are used especially if one of the following risk factors is present;
 - Gestational age > 20 week.
 - Preoperative RR > 24 / min.
 - Preoperative temperature > 100.4 F. degree.
 - Fluid load > 4 liters in the 1st 28 hours.

Postoperative Management

- 1- Continue monitoring the fetal heart rate and uterine activity.
- 2- Postoperative pain relief by;
 - Systemic medications (they can decrease fetal heart rate viability).
 - Regional techniques.
- 3- Care is taken to avoid DVT.
- 4- Maintain maternal oxygenation and uterine displacement.

CHAPTER 7

NEONATAL RESUSCITATION

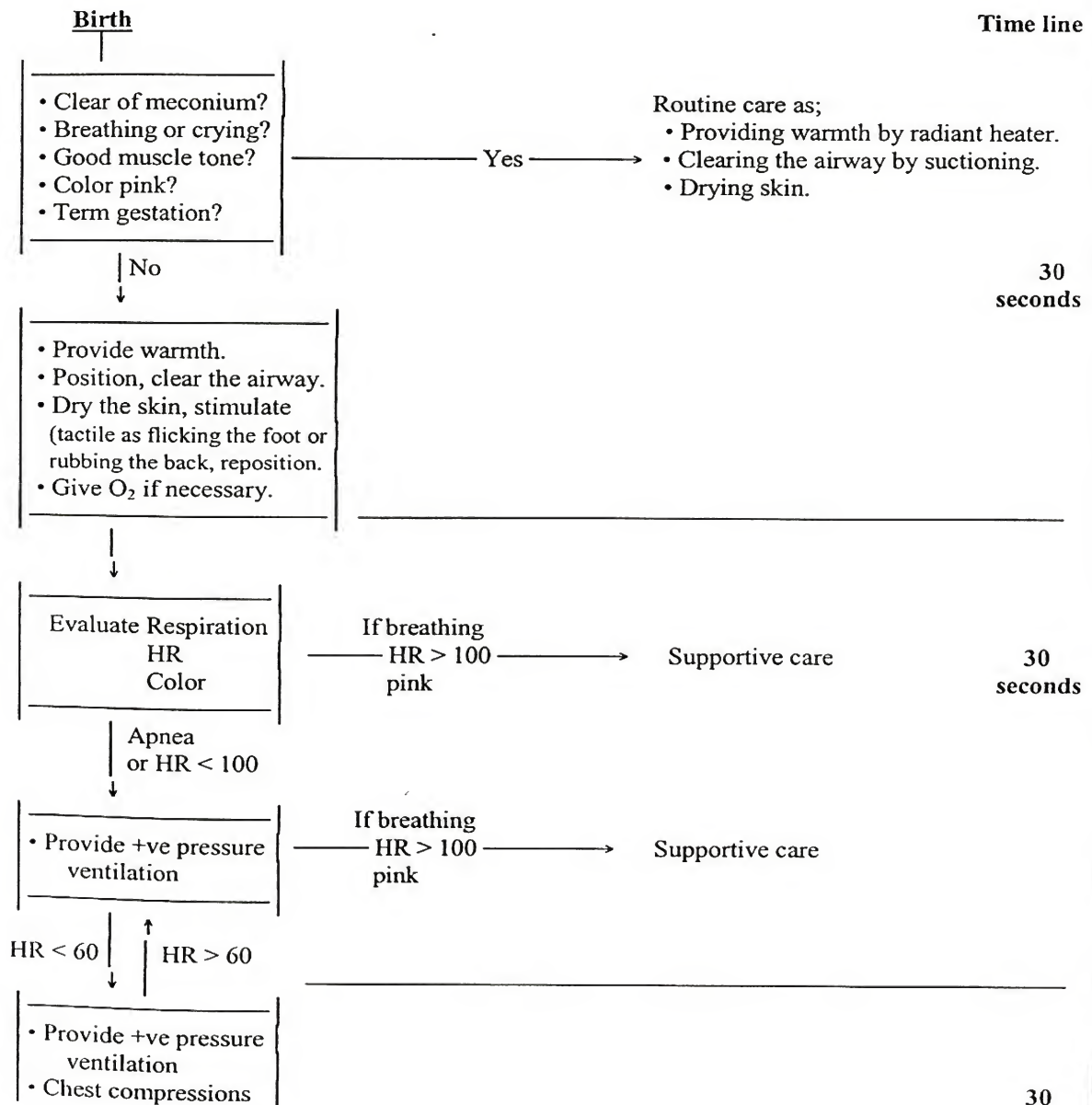
It is usually done by obstetricians, pediatricians or nurse specialist. The anesthesiologist may be requested to provide brief assistance in resuscitation, but that must not be on expense of mother care.

- During care of a depressed neonate at least 2 persons must be available for respiratory resuscitation and cardiac resuscitation \pm 3rd one for i.v fluid and drugs.

- Neonatal resuscitation equipment and drugs should be readily available in the delivery room.

Protocol of Neonatal Resuscitation

By The American Heart Association / American Academy of Pediatrics (2000)



NEONATAL RESUSCITATION**N.B.; Artificial Ventilation:** (+ve pressure ventilation)**Indications:**

- 1- Persistent apnea or inadequate respiration i.e. persistent cyanosis in spite of giving 100% O₂ by mask.
- 2- Persistent bradycardia < 100 /min.
- 3- Cardiac arrest.
- 4- Apgar score 0-2.

Technique:

- Ventilation is done by; - Jackson's Rees modifications of Ayre's T- piece with manual compression of the bag
- By using; • A face mask.
 - A laryngeal mask size 1 which has been used recently in resuscitation for at least 2.5 Kg and 35 week gestation or larger.
- Or • Intubation by a straight bladed laryngoscope (Miller 00 or 0) usually.
 - E.T.T. size: < 1Kg —————→ 2.5 ID.
 - 1 – 2 Kg —————→ 3.0 ID.
 - > 2 Kg —————→ 3.5 ID.

The correct size is indicated by the small leak around the tube with 20 cm H₂O.

E.T.T. length: Tip to lip = 6 cm + body weight in Kg.

But, chest auscultation is very important.

Indication of intubation - ineffective face mask.

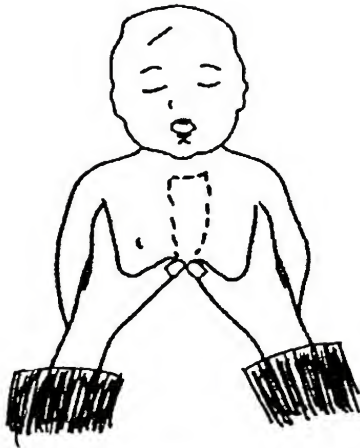
- the need for prolonged mechanical ventilation.
- a route for medications

N.B.; Chest Compression**(Cardiac Resuscitation):****Indications:**

- 1- If HR is < 60/min.
- 2- If there is cardiac arrest.

Technique:

- Place both thumbs at the junction of the middle and the lower 1/3 of the body of the sternum and let the fingers encircle the body to support the back (figure 7-1).
- Compress the sternum 1.5-2 cm (to a depth of about 1/3 of the antero-posterior diameter of the chest) at rate of 90-100/ min.
- Do cardiac: ventilation ratio of 3:1.



Using encircling fingers



Using 2 fingers (less efficient)

Figure 7-1; Chest compression in the newborn

Neonatal Assessment (APGAR score):

Signs	Score		
	0	1	2
Appearance (color)	Blue	Pink body and blue extremities	All pink
Pulse (heart rate) <small>Normally 120-160 /min by auscultating the pericardium or the base of the umbilical cord.</small>	Absent	< 100 / min	> 100 / min
Grimace (reflex irritability) as a response to nasal catheter insertion.	Absent	Grimace	Coughing, sneezing & crying
Attitude (muscle tone)	Flaccid	Some flexion of the extremities	Active motion & good flexion
Respiratory effort <small>Normal RR 30-60 /min by chest auscultation</small>	Absent	Slow & irregular	Good & strong crying

- It is done at **1 minute** (correlates with **survival**) after birth.
and **5 minutes** (correlates with **neurologic outcome**) after birth.
- At 1 minute assessment:
 - Score 8-10 → Vigorous "most babies".
Nothing is needed, except **general care** as above.
 - Score 5-7 → Mildly asphyxiated neonates.
They usually respond to **vigorous stimuli** and **O₂** blown over their face.
If not, they should be ventilated with 80-100 % O₂ by bag and mask.
 - Score 3-4 → Moderately asphyxiated neonates.
They need ventilation with **ETT** and **correction of the acidosis** by NaHCO₃
 - Score 0-2 → Severe asphyxiated neonates.
They usually need **mechanical ventilation** and **chest compression**.
- If at 5 min assessment, the score is < 7, do additional assessment every 5 min, until 20 min have passed or until 2 successive scores ≥ 7.

NEONATAL RESUSCITATION**Drug Therapy in Neonatal Resuscitation****Routes:**

1. Umbilical vein (one in number).
2. Umbilical artery (two in number) (Figure 7-2).
3. Peripheral veins.
4. Endotracheal instillation: for drugs as Lidocaine, Epinephrine, Atropine, and Naloxone (LEAN) with delayed onset and peak.

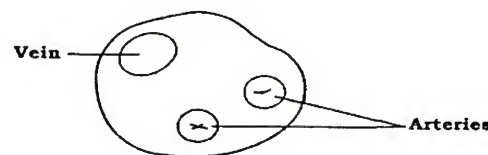


Figure 7-2; Cross-section of the umbilical cord

1- Correction of Acidosis:

- Respiratory acidosis is corrected by continuous ventilatory support.
- Metabolic acidosis is corrected by **NaHCO₃ infusion**.
 - Dose in mEq = $0.4 \times \text{Body weight in Kg} \times \text{Base deficit (by arterial blood gases)}$.
 - If resuscitation is prolonged > 5 min. (especially if arterial blood gases is not available) give 2 mEq/Kg i.v. of 0.5 mEq/mL solution empirically.
 - Precautions:
 - Adequate ventilation should be continued.
 - Give 0.5 mEq/mL solution, at a slow rate < 1 mEq /Kg / min to avoid hyper-tonicity and intracranial hemorrhage.

2- Epinephrine:

Indications: It is the single most useful drug even with bradycardia.

- Persistent bradycardia < 60/min or asystole in spite of adequate ventilation and cardiac compression. It is the single most useful drug even with bradycardia.
- Hypotension.

Dose: 0.01-0.03 mg/kg (0.1-0.3 mL/kg of 10 000 solution) can be repeated every 3-5 minutes, i.v.

or 0.1 mg/kg diluted to 5 mL endo-tracheally in case of arrest and followed by 5 manual ventilation.

N.B.; Atropine 0.03 mg/kg can be used only for vagally mediated bradycardia.

Isoprenalolol 0.1-1 mg/kg/min.

N.B.; Bradycardia of neonates is rarely due to vagal stimulation so, atropine is rarely used.

3- Calcium:**Indications:**

- Documented hypocalcemia.
- Neonates suspected of Mg intoxication from mothers receiving MgSO₄. They are hypotonic, hypotensive, hypoventilated neonates.
- Hyperkalemia.
- Ca⁺⁺ channel blocker excess.

Dose: Calcium chloride 30 mg/kg.

Calcium gluconate 100 mg/kg.

4- Naloxone:

Indications: to reverse respiratory depression of narcotics given to the mother in the last 4 hrs of labor.

N.B.; In narcotic addicted mothers, it may precipitate withdrawal symptoms in neonate. So, it is not used.

Dose: 0.01 mg/kg i.v.

0.02 mg/kg i.m or s.c. or endo-tracheally.

5- Glucose:

Indications: only if neonatal hypoglycemia is documented because glucose increases lactic acid production which aggravates CNS injury.

Dose: 8 mg/kg/min or oral feeding 2-3 mL/kg D_{10%}W.

6- Surfactant:

Indications: to the premature neonates with respiratory distress syndrome.
Endo-tracheally via ETT.

Immediate Neonatal Emergency**A- Medical Neonatal Emergency:****1- Meconium Stained Neonates (& Meconium Aspiration Syndrome):**

- **Incidence:** 10% of all deliveries.

- **Cause:** It usually occurs after 34 weeks of gestation.

As intrauterine arterial **hypoxemia** (i.e. fetal distress) increases gut motility and causes defecation, this leads to presence of meconium in the amniotic fluid (meconium is the break down product of swallowed amniotic fluid, GIT cells and secretions). Thick meconium occurs with severe fetal distress. With more hypoxia, **gasping** occurs causing inhalation of the meconium mixed amniotic fluid which reaches the trachea and large airways i.e.

meconium aspiration.

On initial respirations, meconium is pushed to the small airways obstructing them causing **ventilation/perfusion mismatching**. This leads to severe respiratory distress (occurring in 10% of meconium stained neonates). Death occurs in 10% of these patients.

- **C/P:** - Respiratory rate is $\geq 100/\text{min}$, and cyanosis.

- Decreased lung compliance (like infant respiratory distress syndrome).

- In severe cases, pulmonary hypertension causes right to left shunting via the patent foramen ovale and ductus arteriosus i.e. persistence of fetal circulation.

- Pneumothorax occurs in 10% of cases.

- **Treatment:**

1. Just after delivery of the head, **suction of the mouth, nose, and posterior pharynx** (and before shoulder delivery).

2. After complete delivery of the baby and transferring to under radiant heater, **ETT** is inserted and suction is done before the 1st breath is taken. Suction can be repeated till no meconium is obtained (usually within 3 times).

3. Supply **O₂** by face mask and manage the case as the above protocol.

4. **Suction of the stomach** is performed to prevent passive regurgitation of any meconium.

2- Hypovolemia in Neonates:

- **Causes:**

1- Early clamping of the umbilical cord.

2- Holding the neonate above the introitus before cord clamping.

3- Twin to twin transfusion.

4- Placental transection during C.S.

5- Prematurity.

6- Sepsis.

7- Maternal hemorrhage.

N.B.; Causes of hypotension in neonates:

Hypovolemia, hypoglycemia, hypocalcemia, hypomagnesemia and hypothermia.

- **C/P:** Signs of shock.

1- Skin color: **pallor** that persists after oxygenation.

2- Pulse volume: **faint pulse** with adequate heart rate (posterior tibial artery).

3- **Cold** extremities.

4- ABP: decreases because in neonates the ABP generally correlates with the intravascular volume.

NEONATAL RESUSCITATION

N.B.; Normal ABP depends on birth weight: and ranges from 50 / 25 mm Hg for 1-2 kg babies
to 70 / 40 mm Hg for > 3 kg babies.

5- Poor response to resuscitation.

- **Treatment:**

• By **intravascular volume expanders** e.g. whole blood, plasma, 5% albumin, normal saline or lactated ringer's solution.

• Dose: 10 mL/kg over 5-10 minutes.

• Route: Care must be taken not to introduce any air.

a- Umbilical vein cannulation:

- By 3.5 F or 5 F umbilical catheter.

- The tip of the catheter should be just below the skin level allowing free backflow of blood because more advancing of the catheter causes liver injury by hypertonic fluid given later.

b- Umbilical artery cannulation:

- By specially designed umbilical artery catheters.

- It allows fluid and drug infusion + blood samples for arterial blood gases.

3- Neonatal Hypoglycemia:

- **Causes:** - Babies of diabetic mothers.

- Intrauterine growth retardation.

- After severe intrauterine fetal distress.

- C/P: Hypotension, tremors and seizures.

4- Pierre Robin Syndrome:

- C/P: There are glossoptosis, micrognathia, and cleft palate. Respiratory obstruction occurs when the tongue is sucked against the posterior pharyngeal wall by -ve intra-pharyngeal pressure.

- **Treatment:**

1. Establish the **airway** by oral airway or pulling the tongue forward with a clamp.

2. **Prone position** displaces the tongue away from the posterior pharyngeal wall.

3. A small **nasopharyngeal airway** can be used to prevent -ve pressure.

4. No muscle relaxant is allowed, as paralysis causes obstruction of ventilation.

5- Prematurity:..... "see pediatrics".

With increased risk of;

• Respiratory distress syndrome.

• Broncho-pulmonary dysplasia.

• Apnea spells.

• Hypoglycemia.

• Hypocalcaemia.

• Sepsis.

• Intracranial hemorrhage.

• Retinopathy of Prematurity.

• Kernicterus.

B- Surgical Neonatal Emergency

1- Choanal Stenosis and Atresia:

- C/P: - The neonate has good breathing efforts and obligatory nasal breathing, but no air entry causing cyanosis.

- Failure to pass a small catheter through each nare.

- **Cause:**

& Treatment:

1- **Congenital** (anatomical); an oral airway is needed till surgical correction.

2- Obstruction by **blood, mucus or meconium**; nasal suction is needed.

3- Nasal mucosa **congestion**, by opioids (as heroin addiction); phenylephrine nasal drops are needed.

2- Congenital Diaphragmatic Hernia:

Severe respiratory distress at birth causing cyanosis....."see pediatric anesthesia".

3- Laryngeal Anomalies & Subglottic Stenosis:

C/P: - Stridor at birth.

- Insertion of a tube into the trachea beyond the obstruction alleviates the symptoms.

4- Esophageal Atresia:....."see pediatric anesthesia".

5- Abdominal Wall Defects:....."see pediatric anesthesia".

6- Pyloric Stenosis:....."see pediatric anesthesia".

7- Necrotizing Entero-colitis: "see pediatric anesthesia".

8- Imperforate Anus.

9- Hirschsprung's Disease.

10- Congenital Hyper-insulinism.

11- Lobar Emphysema.

12- Congenital heart diseases.

Q: What are the anesthetic managements of neonatal emergencies?

A: Discuss medical and surgical neonatal emergencies.

Q: What are the anesthetic managements of surgical neonatal emergencies?

A: Discuss surgical neonatal emergencies.

CHAPTER 8

ANESTHESIA WITH RESPIRATORY DISEASES

Physiologic Consideration

Mechanics of Ventilation

Compliance (C)

It is volume change per unit of distending pressure (mL/cm H₂O). It is due to tissue elasticity and surface tension.

$$C_{\text{lung}} = \frac{\text{Change in lung volume}}{\text{Change in trans-pulmonary pressure}} = 150 - 200 \text{ mL/cmH}_2\text{O}$$

$$C_{\text{chest}} = \frac{\text{Change in chest volume}}{\text{Change in trans-thoracic pressure}} = 200 \text{ mL/cm H}_2\text{O}$$

$$\text{Total respiratory system compliance} = 86 - 100 \text{ mL/cm H}_2\text{O}$$

$$\frac{1}{C_{\text{total}}} = \frac{1}{C_{\text{chest}}} + \frac{1}{C_{\text{lung}}}$$

Static Pressure-Volume Curve (Compliance Curve)

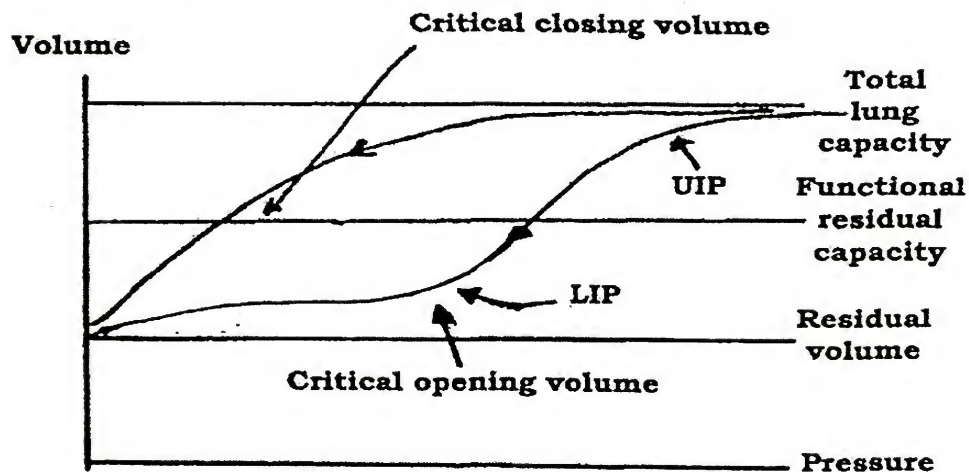


Figure 8-1; Static pressure volume curve

There are 2 critical regions in which pulmonary compliance is very poor (figure 8-1);

- The first region is slightly above the residual volume and denotes a critical opening volume whereby recruitable alveoli have the propensity to collapse during tidal breathing. Cyclic opening and closing of these alveolar units has been implicated as a cause of ventilator-induced lung injury. The determination of the lower inflection point (LIP) on

the static pressure-volume curve allows the clinician to set the PEEP to 2 cm H₂O above this critical opening volume to prevent alveolar collapse and promote recruitment.

- The compliance of the lung markedly improves beyond this point until it reaches higher lung volumes, labelled **upper inflection point (UIP)**.

The ideal volume can be extracted from this curve as the volume contained between the LIP and the UIP. Similarly, ideal compliance can be derived from the slope of this steep portion (region between LIP and UIP).

Static Lung Volumes

All volumes are more related to height than weight.

Definitions: (figure 8-2)

- **Tidal Volume (V_t):** It is each normal quite breathing = 7 – 10 mL /Kg.
- **Inspiratory Reserve Volume (IRV):** It is the maximal additional volume that can be inspired above V_t.

- **Expiratory Reserve Volume (ERV):** It is the maximal additional volume that can be expired below V_t.

- **Residual Volume (RV):** It is the volume remaining after maximal expiration.

- **Functional Residual Capacity (FRC):**

- It is the volume remaining after normal expiration i.e. resting volume.

- **Factors decreasing FRC:**

1. Prone position.
2. Supine, head down position.
3. Anesthesia intraoperatively.
4. Abdominal and thoracic surgery postoperatively.
5. Pulmonary fibrosis: It decreases lung compliance.
6. Pulmonary edema: It decreases lung compliance.
7. Obesity.
8. Abdominal swelling e.g. pregnancy, tumor, ascitis: They decrease chest compliance.
9. Thoracic cage distortion: It decreases chest compliance.
10. Reduced muscle tone.

- **Factors increasing FRC:**

1. Increased intra-thoracic pressure e.g. PEEP, CPAP.
2. Upright posture.
3. Emphysema: It decreases lung elasticity.
4. Asthma.
5. Young age.
6. Male gender.
7. Increased height.
8. Decreased weight.

- **Vital Capacity (VC):** It is the maximal volume of gas that can be exhaled following maximal inspiration = 50-55 mL/Kg.

- **Closing Volume (CV):**

- It is the volume of the lung where small airways (without cartilages) in the dependent parts of the lung begin to collapse during expiration.

- Normally, it is less than the FRC, but greater than the RV.

- It can be demonstrated by expiration to the RV which is inevitably followed by a sigh to re-expand the collapsed lung.

- **Closing Capacity (CC):** It is the closing volume + residual volume.

- CC increases by age as at 44 years CC equals FRC in supine position.

At 66 years CC is \geq FRC in upright position.

(Due to decreased FRC and not due to increased CC).

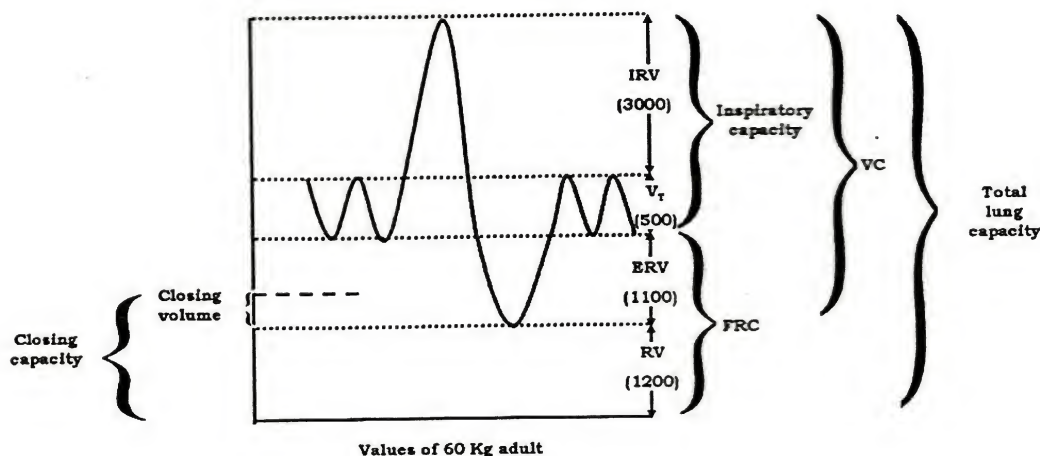
ANESTHESIA WITH RESPIRATORY DISEASES

Therefore, normally there is a decrease in PaO_2 with age.

If CC is $>$ FRC, the alveoli are perfused, but not ventilated (i.e. intrapulmonary shunt) causing hypoxemia.

- CC is not affected by posture

- CC is measured by trace gas (xenon¹³³) which is inhaled near residual volume and then exhaled from total lung capacity.



N.B.; Capacity i.e. 2 or more volumes

Figure 8-2; Static lung volumes and capacities

Dynamic Lung Volumes

- **Forced Vital Capacity (FVC):** It measures vital capacity as expiration is as hard and as rapid as possible.
- **Forced expiratory volume in the 1st second (FEV₁):** It is the volume that is expired in one second during FVC.
- **FEV₁/FVC ratio:** It is proportional to the degree of airway obstruction
It is normally = 80 %.

Dead Space

It is that part which does not participate in gas exchange. It is formed of;

1. Anatomical Dead Space:

It is the tracheo-bronchial tree down to respiratory bronchioles.

It is normally = 150 mL in an average adult = 2.2 mL/Kg.

2. Alveolar Dead Space:

It is the alveoli that are not perfused. It is normally = Zero "absent"

Physiologic Dead Space = Anatomical dead space + alveolar dead space

The ratio of dead space (V_d) to tidal volume (V_t) is more useful. Normally, it is 0.3

Factors affecting the dead space:

a- Factors increasing the dead space:

1. Upright posture.
2. Neck extension.
3. Age.
4. +ve pressure ventilation.
5. Anticholinergics which cause bronchodilatation.
6. Decreased pulmonary perfusion e.g. pulmonary emboli, hypotension.
7. Lung disease.

b- Factors decreasing the dead space;

1. Supine posture.
2. Neck flexion.
3. E.T.T.

Ventilation/Perfusion Matching

Distribution of Ventilation:

Inspired gas is directed towards the **dependant parts of lungs** due to the differences in the compliance of different parts of lung. These differences in compliance are because the weight of the lung produces less -ve intra-pleural pressure at the base compared with the apex. Therefore, the lung at the base is less expanded with smaller resting volume so, it expands better on inspiration and has better compliance and better ventilation (figure 8-3).

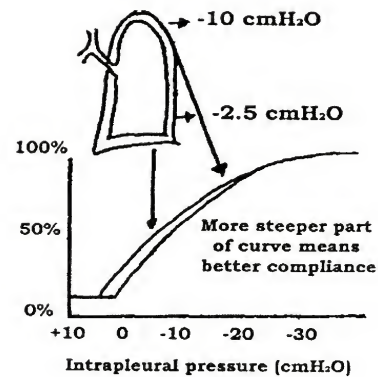


Figure 8-3; Distribution of ventilation

Distribution of Pulmonary Perfusion:

- The lower (dependent) portions of the lung receive greater blood flow than the upper (non dependent) areas.

This is due to the effect of **gravity** (figure 8-4).

- Each lung can be divided into 3 classic **West zones**.

• **Zone I (upper zone):** $P_A > P_a > P_{\bar{u}}$

It represents the alveolar dead space.

It does not occur normally, but occurs with hypovolemia and with increased alveolar pressure.

• **Zone II (middle zone):** $P_a > P_A > P_{\bar{u}}$

Pulmonary capillary flow is intermittent and varies during respiration.

• **Zone III (lower zone):** $P_a > P_{\bar{u}} > P_A$

Pulmonary capillary flow is continuous and proportional to the arterial-venous pressure gradient.

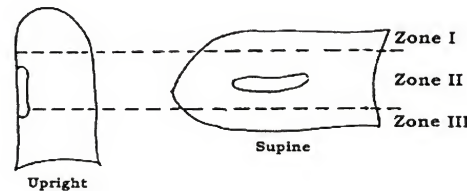


Figure 8-4; Distribution of pulmonary perfusion

Ventilation (\dot{V}) / Perfusion (\dot{Q}) Ratio

$\frac{\dot{V}}{\dot{Q}} = \frac{5 \text{ L/min}}{5 \text{ L/min}} = 1$ (average 0.3 – 3) normally.

$\dot{Q} = 5 \text{ L/min}$

If $\dot{V} > \dot{Q}$, the ratio is > 1

And if \dot{Q} is absent, the ratio = infinity (∞) i.e. Alveolar dead space.

If $\dot{Q} > \dot{V}$, the ratio is < 1

And if \dot{V} is absent, the ratio = Zero i.e. Intra-pulmonary shunt.

Shunt

Definition: The process where by desaturated mixed venous blood from the right heart **returns** to the left heart without being resaturated with O_2 in the lungs (i.e. right to left shunt).

Effects: It dilutes and decreases arterial O_2 content resulting in **hypoxemia**.

N.B.; Left-to right shunt (in the absence of pulmonary congestion) does not produce hypoxemia.

ANESTHESIA WITH RESPIRATORY DISEASES

Types: Intrapulmonary shunts are either;

a. **Absolute Shunt:** It refers to anatomic shunts where V'/Q' is zero (i.e. no ventilation). This produces hypoxemia which can not be corrected.

b. **Relative Shunt:** It refers to areas of lung with a low but finite V'/Q' ratio.

This produces hypoxemia which can be partially corrected by increasing the inspired O_2 concentration.

Venous Admixture ($Q's$)

Definition: It is the amount of mixed venous blood that would have to be mixed with pulmonary end-capillary blood to account for the difference in O_2 tension between arterial and pulmonary end-capillary blood (figure 8-5).

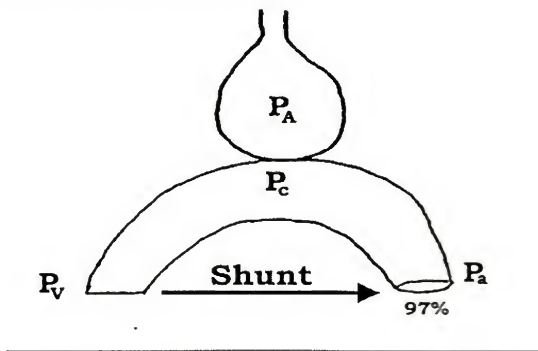


Figure 8-5; Venous admixture

- If there is no shunt (i.e. no venous admixture), the O_2 tension in pulmonary end-capillary blood will be equal to that in arterial blood.

- Pulmonary end-capillary blood is considered to have the same concentration as alveolar gas ($P_A O_2$).

- Actually, there is a difference between $P_A O_2$ and $P_a O_2$ which is due to;

1- **Venous admixture;** Dilution of pulmonary end-capillary blood by blood which has bypassed the lung as the bronchial circulation, the thebesian veins (which drain directly into the heart) and cardiac anomalies.

2- The diffusion gradient across the alveolar capillary membrane.

3- Blood which has come from areas of the lung with low ventilation i.e. V'/Q' ratio < 1 .

The venous admixture in normal individuals (physiologic shunt) is typically less than 5%.

$$\text{Virtual shunt fraction} = \frac{Q's}{Q't} = \frac{C\bar{c}O_2 - CaO_2}{C\bar{c}O_2 - C\bar{v}O_2}$$

$C\bar{c}O_2$ = O_2 content of end pulmonary capillary blood in mL/100 mL blood.

CaO_2 = O_2 content of arterial blood in mL/100 mL blood.

$C\bar{v}O_2$ = O_2 content of mixed venous blood in mL/100 mL blood.

$Q's$ = Venous admixture.

$Q't$ = Total cardiac output.

Mixed Venous O_2 Tension ($P\bar{v}O_2$)

- It is normally 40 mm Hg.

- It represents the overall balance between O_2 consumption and O_2 delivery.

- A true mixed venous blood sample contains venous drainage **mixed from the superior vena cava, the inferior vena cava and the heart** so, it must be obtained from the pulmonary artery catheter.

The Oxygen Cascade

Is a convenient method for demonstrating the steps in the concentration gradient for O₂ between the atmosphere and the mitochondria (figure 8-6).

Two rules of thumb;

- Partial pressure in mm Hg = % x 7.6
- Partial pressure in Kpa = %

1- Dry Atmospheric Air:

It contains 21 % O₂ concentration.

$$\begin{aligned} \text{Partial pressure of inspired O}_2 (\text{PiO}_2) &= \text{Barometric pressure (P}_B) \times \text{FiO}_2 \\ &= 760 \text{ mm Hg} \times 0.21 = 159.6 \text{ mm Hg} \end{aligned}$$

2- Humidified Air at 37 °C:

Humidification occurs by upper airway causing addition of water vapor which in turn decreases PiO₂ i.e. the inspired gas is diluted by the presence of water vapor.

$$\begin{aligned} \text{So, PiO}_2 &= (P_B - P_{\text{H}_2\text{O}}) \times \text{FiO}_2 \\ &= (760 - 47) \times 0.21 = 149.3 \text{ mm Hg} \end{aligned}$$

Where P_{H₂O} is the saturated vapor pressure of water at body temperature (37°C). Normally, it is 47 mm Hg.

3- End- expiratory gas (E):

The inspired gas is further diluted by the addition of CO₂ and the removal of O₂ in the alveolus.

With a normal diet, slightly less CO₂ is produced than O₂ is consumed (respiratory quotient "RQ" < 1.0).

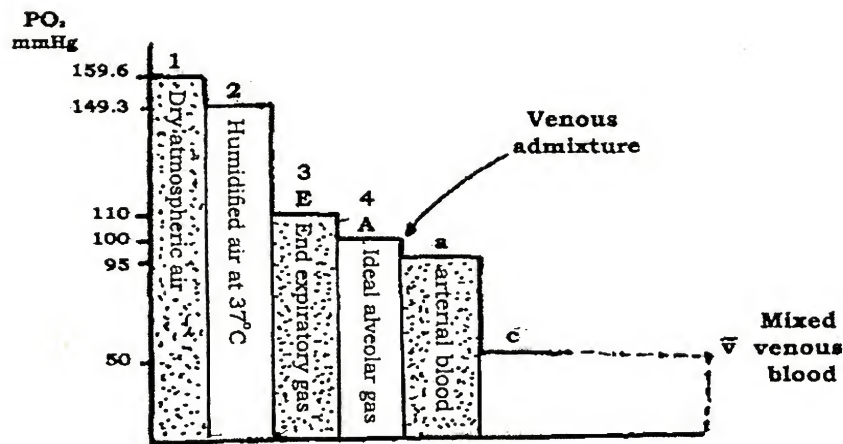


Figure 8-6; The O₂ cascade

4- Ideal Alveolar Gas (A):

PAO₂ is determined by the alveolar air equation.

$$\text{PAO}_2 = \text{PiO}_2 - \frac{\text{PACO}_2}{\text{RQ}} = 110 \text{ mm Hg}$$

As the difference between PACO₂ and PaCO₂ is very small so, the equation can be written as follows;

$$\text{PAO}_2 = \text{PiO}_2 - \frac{\text{PaCO}_2}{\text{RQ}}$$

- Respiratory quotient (RQ) is usually not measured. It is assumed to be 0.8 at room air and 1 at O₂-enriched mixture.

ANESTHESIA WITH RESPIRATORY DISEASES

- If PaCO_2 increases to > 75 mm Hg, hypoxia occurs (i.e. PAO_2 is < 60 mm Hg) at room air, but not at high inspired O_2 concentration.

(Simple method of approximation PAO_2 in mm Hg is to multiply % of inspired O_2 concentration by 6 thus at 40 %, PAO_2 is $6 \times 40 = 240$ mm Hg.

5- Mean Capillary Blood (\bar{c}):

- Pulmonary end-capillary O_2 tension ($\text{P}\bar{c}\text{O}_2$) may be considered identical to PAO_2 as PAO_2
- $\text{P}\bar{c}\text{O}_2$ gradient is minute.
- $\text{P}\bar{c}\text{O}_2$ is nearly 100 mm Hg.
- $\text{P}\bar{c}\text{O}_2$ is dependent on;

- 1- The rate of O_2 diffusion across the alveolar-capillary membrane. It is facilitated by;
 - The large capillary surface area in the alveoli.
 - 0.4-0.5 μm thickness of the alveolar-capillary membrane.
- 2- Enhanced O_2 binding to Hb at saturation above 80 %.
- 3- Transit time via capillaries.

$$= \frac{\text{Pulmonary capillary blood volume}}{\text{CO (Pulmonary blood flow)}} = \frac{70 \text{ mL}}{5000 \text{ mL/min}} = 0.8 \text{ sec}$$

- Maximum $\text{P}\bar{c}\text{O}_2$ is usually attained after only 0.3 seconds providing a large safety margin.
- O_2 uptake from alveolar gas to blood is normally limited by pulmonary blood flow (and O_2 binding to Hb), and not by O_2 diffusion across the alveolar-capillary membrane (O_2 diffusing capacity).
- O_2 diffusing capacity ($\text{D}_\text{L}\text{O}_2$) = $\frac{\text{O}_2 \text{ uptake}}{\text{PAO}_2 - \text{P}\bar{c}\text{O}_2}$

N.B.; Because $\text{P}\bar{c}\text{O}_2$ cannot be measured accurately, measurement of carbon monoxide diffusion capacity instead is used to assess gas transfer across the alveolar-capillary membrane.

Because carbon monoxide has a very high affinity for Hb, $\text{P}\bar{c}\text{CO}$ can be considered zero. Therefore, $\text{D}_\text{L}\text{CO} = \frac{\text{Carbon monoxide uptake}}{\text{PACO}}$

Decreased $\text{D}_\text{L}\text{CO}$ represents a decrease in gas transfer across the alveolar-capillary membrane e.g. due to;

- Abnormal V'/Q' ratios.

- Extensive destruction of alveolar-capillary membrane.
- Very short capillary transient times.

6- Arterial O_2 Tension (PaO_2):

$$\text{PaO}_2 = 102 - \frac{\text{Age}}{3} = 60\text{-}100 \text{ mm Hg}$$

- It is less than $\text{P}\bar{c}\text{O}_2$ due to venous admixture.

Transport of O_2 in Blood

It is carried in blood in two forms.

I. Physical Part i.e. Dissolved O_2 :

It is estimated by Henry's law

"The concentration of any gas in solution is proportional to its partial pressure"

Gas concentration = $\alpha \times$ partial pressure

α = gas solubility coefficient for a given solution at a given temperature.

For O_2 , it is = 0.003 mL/dL /mm Hg.

Even with PAO_2 of 100 mm Hg, the maximum amount of O_2 dissolved in blood is very small = $0.003 \times 100 = 0.3$ mL /dL solution.

II. Chemical Part i.e. O_2 Bound to Hb:

Each gram of Hb can theoretically carry up to 1.38 mL of O_2 (in some references 1.34)

Hb-Dissociation Curve

- It is **sigmoid (elongated S)** in shape due to successive oxygenation of the 4 heme groups of Hb molecule in steps and their increased affinity to O_2 after the 1st heme group is oxygenated (figure 8-7).
- **Hb saturation:** is the amount of O_2 bound as a percentage of its total O_2 -binding capacity.
- **P_{50}** is the O_2 tension at which Hb is 50 % saturated. It is normally = 26.6 mm Hg.
- **Normal curve shows;**
 - At alveolar O_2 tension (PAO_2) **100 mm Hg**; PaO_2 is **> 90 mm Hg** (about 95 mm Hg) and SaO_2 is nearly **100 %** (about 97.5 %) and becomes almost independent of PaO_2 . This ensures adequate O_2 supply to the tissues.
 - At PaO_2 **70 mm Hg**; SaO_2 is **93%** i.e. PaO_2 can decrease by about 1/3 (as occurs in high altitudes and some pulmonary diseases) without a large decrease in SaO_2 %.
 - At PaO_2 **60 mm Hg**; SaO_2 is **90%**.
 - At PaO_2 **40 mm Hg** (that of venous blood); SaO_2 is **75 %** i.e. arterial Hb is about 25 % desaturated.

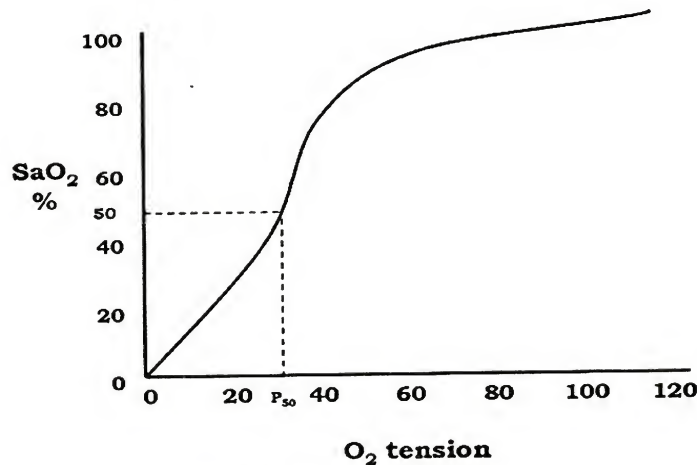


Figure 8-7; Hb-Dissociation Curve

- At PaO_2 **40 to 20 mm Hg**; the curve is steep (vertical) where a slight decrease in PaO_2 is associated with a marked decrease in % saturation (thus supplying more O_2 to tissues). This is important in muscle exercise as PaO_2 in active muscles decreases sharply causing more O_2 diffusion from the blood. So, when PaO_2 is decreased, increased desaturation of Hb occurs and consequently more release of O_2 to active muscle occurs (about 3 times as much as during rest).

Factors Affecting the O_2 – Hb Dissociation Curve:

Factors that shift the curve to left i.e. there is ↑ affinity of Hb to O_2 so, less O_2 is delivered and a lower P_{50} is produced.	Factors that shift the curve to right i.e. there is ↓ affinity of Hb to O_2 so, more O_2 is delivered and a higher P_{50} is produced.
<ol style="list-style-type: none"> 1. ↓ H^+ concentration (↑ pH or alkalinity) 2. ↓ $PaCO_2$ 3. ↓ Temperature 4. ↓ Concentration of 2, 3 DPG (Di-phosphoglycerate) in RBCs as stored blood and fetal blood (HbF). 5. ↓ Hb concentration as anemia or hemolysis. 6. Abnormal Hb as carboxy-Hb (carbon monoxide poisoning), met-Hb, cyanide, fetal Hb and sickle Hb. 	<ol style="list-style-type: none"> 1. ↑ H^+ concentration (↓ pH or acidity) 2. ↑ $PaCO_2$ 3. ↑ Temperature 4. ↑ Concentration of 2, 3 DPG (Di-phosphoglycerate) in RBCs as high altitudes, exercise, chronic hypoxia and pregnancy 5. ↑ Hb concentration as polycythemia and pregnancy.

ANESTHESIA WITH RESPIRATORY DISEASES

O₂ Content

It is the sum of O₂ chemically combined with Hb and that physically dissolved in plasma.

$$O_2 \text{ content} = [SaO_2 \times Hb \times 1.38 \text{ mL/dL blood}] + [0.003 \text{ mL O}_2 / \text{dL blood/mmHg} \times PaO_2]$$

When Hb is 15 gm /dL and SaO₂ is 98 %, O₂ content can be estimated.

$$O_2 \text{ content in arterial blood (CaO}_2) = 19.5 \text{ mL/dL}$$

$$O_2 \text{ content in mixed venous blood (C}\bar{v}O_2) = 14.8 \text{ mL/dL}$$

$$\text{Arterio-venous difference (CaO}_2 - C\bar{v}O_2) = 19.5 - 14.8 = 4.7 \text{ mL/dL}$$

$$\text{Total O}_2 \text{ Delivery to Tissues or O}_2 \text{ Flux (D'O}_2) = CaO_2 \times Q_t$$

By Fick equation;

$$O_2 \text{ consumption (V'O}_2) = Q_t \times (CaO_2 - C\bar{v}O_2)$$

$$CaO_2 - C\bar{v}O_2 = \frac{V'O_2}{Q_t} = \frac{250 \text{ mL/min}}{5000 \text{ mL/min}} = \frac{1}{20} = 0.05 \text{ mL} = 5 \text{ mL/dL}$$

So, the A-V difference is a good measure of the overall adequacy of O₂ delivery

Normal extraction fraction for O₂

$$= \frac{CaO_2 - C\bar{v}O_2}{CaO_2} = \frac{5}{20} = 25 \%$$

So, the body normally consumes only 25% of the O₂ carried on Hb.

Control of Breathing

Respiratory Centers:

There are 2 centers in the medulla (figure 8-8);

1- **A dorsal respiratory group:** It is primarily active during **inspiration**.

2- **A ventral respiratory group:** It is primarily active during **expiration**.

- The origin of the basic rhythm is due to either; (not firmly established)

- Intrinsic spontaneous discharge activity in the dorsal group.

Or • Reciprocating activity between the dorsal and ventral groups.

- Just dorsal to the ventral respiratory group is a region called the **pre-Bötzinger complex cells** which seems to be able to generate a pacemaker activity related to voltage-dependent ion channels (much like cardiac pacemaker cells), but it is not clear whether these cells can initiate respiratory rhythm alone or with the help of the dorsal and ventral respiratory groups.

- There are 2 pontine areas influencing the dorsal (inspiratory) medullary center;

- 1- A lower pontine (**apneustic**) center which is **excitatory**.

- 2- An upper pontine (**pneumotaxic**) center which is **inhibitory**.

Both pontine centers appear to fine-tune the respiratory rate and rhythm as a lesion of the brain-stem below the pontine centers causes a medullary gasping pattern of respiration suggesting that the rhythm is generated in the medulla and fine tuned in the pons.

- Respiratory center balances the depth of respiration (tidal volume) against the rate to spend the least energy of breathing as;

- Increased elastic work of breathing (e.g. pulmonary edema or fibrosis), increases the respiratory rate.

- Increased resistive work of breathing (e.g. asthma), increases the depth of breathing (V_t).

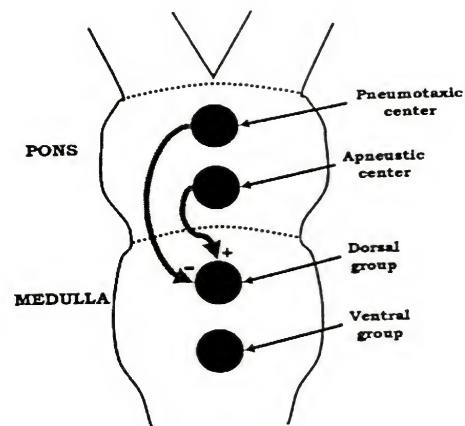


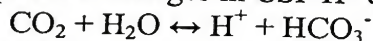
Figure 8-8; Respiratory centers

Respiratory center is affected by;

I- Central Sensors:

1- Central Chemo-receptors:

- They lie on the antero-lateral surface of the **medulla** (floor of the 4th ventricle) near the ventral respiratory group.
- They respond to changes in CSF H^+ concentration.



As the blood brain barrier is permeable to dissolved CO_2 , but not to HCO_3^- ions, acute changes in $PaCO_2$ are reflected in CSF H^+ concentration. Increased $PaCO_2$ causes increased CSF H^+ concentration which in turn activates central chemo-receptors. This increases alveolar ventilation which reduces $PaCO_2$ back to normal. The reverse also occurs (this is a rapid response).

2- Higher Centers in the Brain Including the Cerebral Cortex as the pattern of respiration is modulated by speech, ingestion of food and drink, and anticipation of exercise.

II- Peripheral Sensors:

Peripheral Chemo-receptors:

- They lie in • Carotid bodies (at the bifurcation of the common carotid arteries). They are the main ones.
- Aortic bodies (surrounding the aortic arch).
- They are stimulated by • Decreased PaO_2 (mainly).
 - Increased $PaCO_2$.
 - Increased H^+ concentration.
 - Decreased arterial perfusion pressure.

Also they are stimulated by cyanide, doxapram, and large doses of nicotine.

The impulses are transmitted through the glosso-pharyngeal nerve to stimulate the respiratory center, which in turn increase alveolar ventilation.

- The receptor activity increases markedly when PaO_2 decreases to less than 50 mm Hg.

As O_2 saturation decreases, the slope of the ventilatory response to CO_2 increases, producing a family of CO_2 response curves (the so-called "**Oxford Fan**") (figure 8-9).

Therefore, when measuring hypercarbic ventilatory response, it is necessary to maintain a constant degree of hypoxic stimulation. This is usually achieved by using high inspired O_2 concentrations, effectively turning off the hypoxic drive mechanism.

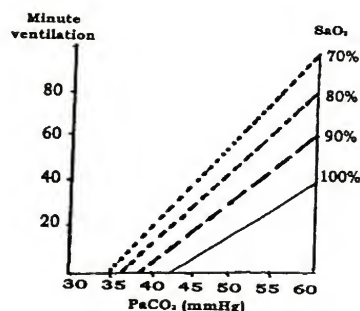


Figure 8-9; Oxford fan

Non-Respiratory Functions of The Lung

1- Acid-base Balance:

The respiratory system makes rapid adjustment by controlling the elimination of CO_2 .

2- Metabolic Function:

a- Synthesis:

- 1- **Surfactant:** it decreases surface tension of the alveoli.
- 2- **Coagulation factors including heparin.**
- 3- O_2 -derived free radicals are produced by neutrophils and macrophages in the lung in response to infection (**superoxide radicals**).

ANESTHESIA WITH RESPIRATORY DISEASES

4- **Histamine** synthesis and release during allergic reactions.

b- Metabolism:

1- Conversion of angiotensin I (inactive) to angiotensin II (active) by **angiotensin converting enzyme** which is bound on surface of pulmonary endothelium.

2- Pulmonary endothelium **inactivates norepinephrine, serotonin, bradykinin, prostaglandins and leukotrienes.**

3- Filtration Function:

- The unique in-series position of the pulmonary capillaries allows them to act as a filter for debris in the blood-stream (e.g. thrombi).

The theoretical pore size of the lung as a filter is about 70 μm although in practice, much larger particles can traverse the lungs via A-V connections.

- Active proteolytic system, plasmin activators, heparin, and thromboplastin facilitate breakdown of entrapped fibrin debris.

4- Pulmonary Defense Mechanisms:

1- **The nose and the tracheo-bronchial tree:**

By their lining of mucus-secreting ciliated epithelium, as cilia sweep the mucus coat with the entrapped particles to the pharynx.

2- **Cough.**

3- **Pulmonary macrophages:**

They phagocytose inhaled particles and produce proteases and O_2 free radicals (superoxide radicals) to kill the bacteria.

N.B.; Lungs contain α_1 antitrypsin to inactivate the proteases and contain superoxide dismutase to inactivate superoxide radicals to prevent damaging themselves.

4- **Immunoglobulin A (IgA):**

It is secreted in pulmonary mucus and contributes to the killing of micro-organisms.

Anesthesia With Respiratory Diseases

Preoperative Patient Evaluation

I- Detect the **preoperative pulmonary risk factors**, which can predict the possibility of postoperative complications.

1) **Preexisting pulmonary disease:**

It is detected by 5 cardinal symptoms;

- Dyspnea and its relation to exertion.
- Cough (productive or not).
- Purulent sputum indicates active infection which should be treated preoperatively.
- Chronic copious sputum indicates bronchiectasis or lung abscess.
- Wheeze indicates the degree of obstructive lung disease.
- Hemoptysis.
- Chest pain.

2) **Smoking.....** "See chapter of practical conduct of anesthesia".

3) **Obesity (Morbid Obese):** It decreases FRC and increases the work of breathing and the risk of D.V.T.

4) **Age > 60 years.**

5) **Prolonged general anesthesia > 3 hrs.**

6) **Thoracic or upper abdominal surgery (Vertical > horizontal incisions)**

It decreases the vital capacity (40%) and FRC (60-70%), this effect is maximum in the 1st postoperative day and usually lasts for 5-10 days (up to 14 days) postoperatively.

II- Detect the presence of complications e.g. **cor pulmonale.**

III- History of drug intake and their complications as;

- Steroids: give perioperative cover.
- Bronchodilators: continue up to time of surgery.
- Digoxin, diuretics: in patients with cor pulmonale.

IV- Preoperative assessment of other systems e.g. CVS.**Preoperative Patient Preparation****Aim: To reach the optimum respiratory function.****1- Treatment of Bronchospasm:**(if present)

- By aminophylline, β_2 agonists, corticosteroids.....

If there is improvement $> 15\%$ in FEV₁ after bronchodilators, the patient has reversible obstruction so, start long term bronchodilators therapy as the patient will benefit from it. If the patient is already on bronchodilator therapy, continue it perioperatively.

2- Treatment of Pulmonary Infection:

- By proper antibiotics (after culture and sensitivity).

3- Stopping Smoking is very important.

- For at least 12 hrs: Carboxy-Hb (carry carbon monoxide) is decreased. Its half life is 4-6hrs. This increases O₂ carrying capacity.
- For at least 2 days: The stimulant effect of nicotine on CVS is abolished and the improvement of the ciliary function occurs.
- For 1-2 weeks: Sputum volume is decreased.
- For 2 months: Chronic bronchitis is decreased so, bronchospasm and secretions are reduced which improves lung function.
Return of the immune system and hepatic enzymes to normal.

4. Preoperative weight reduction for obese patients before elective surgeries.**5. Chest physiotherapy** to help removal of secretions.**6. Systemic hydration** to help removal of secretions as they become less viscid.**7. Treatment of complications:**

- Pulmonary hypertension e.g. hydralazine, nifedipine.
- Cor pulmonale e.g. digitalis, diuretics, vasodilators..
- Preoperative digitalization if there is history of CHF or supraventricular tachycardia.

Preoperative Investigations as usual +**1. Chest X-ray.****2. ECG:**

- It may show - RV hypertrophy or strain i.e. cor pulmonale.
- Ischemic heart disease.

3. Hematology: may show

- Polycythemia: due to chronic hypoxemia.
- Anemia: which increases tissue hypoxia.
- Leukocytosis: due to active infection.
- Eosinophil count: parallels the degree of airway inflammation and hyper-reactivity in asthma so, it can be used to assess the degree of asthma.

4. Sputum Examination:

C & S test is done for patients with acute infections or chronic lung disease.

It contains eosinophils in bronchial asthma or neutrophils in bronchitis or pneumonia.

5. Arterial Blood Gases Measurement:

Values: 1- Increased PaCO₂ > 45 mm Hg is a prognostic indication of postoperative pulmonary complications (if PaCO₂ is ≥ 50 mm Hg, it indicates the increased need for postoperative ventilation).

ANESTHESIA WITH RESPIRATORY DISEASES

2- Decreased PaO_2 + dyspnea at rest indicates the increased need for postoperative ventilation.

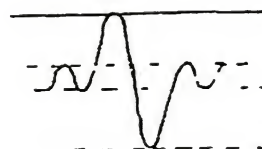
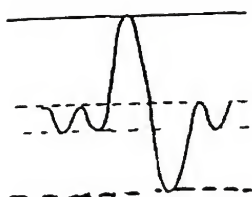
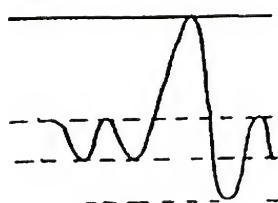
6- Computed Tomography (CT).**7- Magnetic Resonance Imaging (MRI).**

8- Radioisotope Scan to assess regional lung function. It is important before lung resection. The overall lung function is unlikely to be significantly impaired if the resectable area has poor function.

9- Pulmonary Function Tests:

It can differentiate between obstructive and restrictive lung diseases.

If they are less than 50 % of the predicted, postoperative ventilation is needed.

Obstructive Lung DiseaseNormalRestrictive Lung Disease

Pulmonary function tests	Obstructive	Restrictive
(1) - Forced expiratory volume in 1 sec (FEV1): normally > 80% of FVC - Forced vital capacity (FVC).	- ↓↓ due to ↑ airway resistance - little effect	- ↓ due to normal airway resistance - ↓↓ due to ↓ expansion of the lung and chest wall.
So, - FEV1/FVC ratio	- ↓ (< 75% predicted)	- Normal or ↑
2)- Vital capacity (VC)	- Normal /or ↓	- ↓
3)-Total lung capacity (TLC) - Residual volume (RV) - Functional residual capacity (FRC)	- ↑ - ↑ - ↑ i.e. there is air trapping	- ↓ - ↓ - ↓ i.e. there is no air trapping
4) Maximum mid-expiratory flow rate (MMEFR) (= Forced Expiratory Flow or FEF 25-75%). It is obtained by dividing the volume between 25-75% of VC by the corresponding elapsed time. This is the only abnormality present early in the course of the disease.	- ↓ - ↓	- N - N
5) Maximum breathing capacity(MBC) Normally = > 125 L/min	- N	- ↓
6)-Total compliance - Airway resistance - So ; the work of breathing	- ↑ - ↑	- N - ↑

Pulmonary diseases include;

- Obstructive pulmonary disease.
- Restrictive pulmonary disease.
- Pulmonary embolism.
- Others as bronchial carcinoma, tuberculosis.

All finally cause respiratory failure.

Obstructive Pulmonary Diseases**Include:**

1. Acute Obstructive Pulmonary Disease (Bronchial Asthma).
2. Chronic Obstructive Pulmonary Disease (COPD).
3. Bronchiectasis: basal respiratory infection characterized by honey comb appearance in chest X-ray.
4. Cystic Fibrosis: defect in Cl^- ions transport causing viscid secretions of the respiratory tract (causing obstructive disease), pancreatic gland (causing DM)
5. Kartagener syndrome: formed of bronchiectasis, chronic sinusitis, situs inversus.
6. Bronchiolitis Obliterans.
7. Tracheal Stenosis.

All increase airway resistance.

Bronchial Asthma (Acute Obstructive Pulmonary Disease)**(Chronic Asthma)**

Incidence: 3-5 % of population

Pathogenesis:**Types:****Extrinsic (Allergic)**

Specific

Especially in children

**Immunologic (chemically)**

Antigen e.g. dust, pollens, danders bind to IgE on the surface of mast cells in atopic patient.



Degranulation of mast cells



Release of trigger agents

As histamine bradykinin, leukotrienes C,D,E.

PG E₂, F_{2α}, D₂, G₂, Thromboxane A₂

Platelet activating factors

Neutrophil and eosinophil chemotactic factor

Intrinsic (Idiosyncratic)

Non-specific

Especially in adult

**Neurologic (Autonomic)**

Infection, pollution, exercise cold or psychogenic



Imbalance between excitatory (broncho-constriction) and inhibitory (bronchodilatation)



Neurogenic reflex

Parasympathetic (vagal) over-stimulation

Mechanism:

There is interaction between the chemical & autonomic mechanisms.

Common Pathology:

Hyper-irritable (Hyper-reactive /Hyper-responsive)
Chronic inflammatory airway to various stimuli

**Airway re-modeling**

i.e. Structural changes cause airway wall thickening due to;

ANESTHESIA WITH RESPIRATORY DISEASES

- 1- Increased bronchial (bronchiolar) constriction.
- 2- Increased bronchial secretion.
- 3- Increased bronchial edema

↓

Reversible expiratory flow obstruction
 Episodes of dyspnea, cough and wheeze
 + Arterial hypoxemia (no CO₂ retention occurs
 because it is 20 times more diffusible than O₂ and due
 to hyperventilation).

N.B.; Irreversible expiratory flow obstruction occurs in COPD, but many patients show mixed pictures. Increased expiratory airflow > 15% after a bronchodilator is suggestive of bronchial asthma.

N.B.; **Aspirin-induced asthma:** It occurs in patients with triad of asthma + nasal polyps + non-steroidal anti-inflammatory drugs, (NSAIDs) allergy. NSAIDs inhibit cyclo-oxygenase therefore, PGs formation from arachidonic acid is decreased and so, arachidonic acid will form leukotrienes which cause bronchospasm.

Preoperative Management:

- Preoperative evaluation.....
- Preoperative preparation..... "As above".
- Preoperative investigations.....

- The decision to proceed or delay the surgery is taken according to;

A. In Elective Surgery:

- The patient should not be in an attack.
- If the patient is in an attack, it should be treated first (otherwise postpone the surgery).

Treatment of bronchial asthma:

1. Bronchodilators:

- β_2 agonists:
 - Non-selective e.g. epinephrine, isoprenaline i.v. / s.c.
 - Selective e.g. • Fenoterol, Rimiterol aerosol inhaler 100-500 μ g/dose 4 times /day
 - Salbutamol, terbutaline nebulizer, i.v. or oral.

• Methyl-xanthine e.g. aminophylline.

If the patient is already on aminophylline, its plasma level should be checked

- Anticholinergics e.g.: Ipratropium bromide 0.02 mg/puff/6hrs by metered aerosol
- Anti-inflammatory:

- Hydrocortisone:- Loading dose 4 mg/kg
- Maintenance 3 mg/kg/6hrs

It needs several hours (> 6hrs) to become effective.

- Cromolyn Na: to prevent a new attack
 - Inhalation 20 mg capsule containing powder/6hrs.
 - Nebulizer: 10 mg/mL solution
 - Metered aerosol: one mg/puff

B. In Emergency Surgery and the patient is in an attack.

Preoperative intensive therapy is needed by O₂, i.v. aminophylline, i.v. or aerosol β_2 agonist and cortisone.

Premedications:

1. Sedatives: Benzodiazepines is the drug of choice.

2. Anticholinergic Agents: e.g. atropine

- Value:

- Block the vagal reflex-induced bronchospasm.
- Decrease bronchial secretions.

Especially if - Copious secretions are present.

Or - Ketamine was used for induction of anesthesia.

Some physicians avoid its routine use because it increases viscosity of secretions and makes them more difficult to clear (only theoretically).

3. Continue Treatment:

- Bronchodilators: should be continued up to 1 hr before surgery.
- Cromolyn prophylaxis: should be continued up the time of surgery.
- Corticosteroids: are given to patients whom were receiving long term steroid therapy. Hydrocortisone 100 mg for pre- and intra- and 6 hrs postoperatively in the 1st day to compensate for adrenal suppression.

Intraoperative Management

Monitoring: Standard.

Choice of Anesthesia:

A. Regional Anesthesia: controversy exists.

Advantage: - It avoids instrumentation of the airway.

- It allows good postoperative analgesia and more effective cough.

Disadvantages:

1. High spinal or epidural anesthesia (above T6) can;
 - Increase bronchospasm by blocking the sympathetic tone, therefore, unopposed parasympathetic activity occurs.
 - Decreased expiratory reserve volume (by 48 %) and decreased use of accessory respiratory muscles. This produces ineffective cough and retention of secretions which increases postoperative respiratory complications.
2. It can not control ventilation as general anesthesia does.

B. General Anesthesia:

Aim:

1. It avoids pain, emotional stress, and light anesthesia which precipitate bronchospasm.
2. The most critical time for an asthmatic patient is instrumentation of the airway.
3. Drugs that should be avoided that cause;
 - a. Bronchospasm e.g. β_2 blockers.
 - b. Histamine release e.g. curare, atracurium, and morphine.

Induction:

Smooth induction (and emergence)

- Good pre-oxygenation
- **Induction agents:**

The most important thing is to achieve depth of anesthesia than to choose the agent

- Methohexitol, propofol or etomidate are preferred as they cause no histamine release.
- Thiopentone (is most commonly used in adults), but occasionally induces bronchospasm due to exaggerated histamine release.
- Ketamine: i.v. (of choice).
 - It causes a bronchodilator effect (dose-independent) due to inhibition of noradrenaline re-uptake which stimulates the sympathetic system.
 - It should **not** be used in patients **with** high **theophylline** levels as the combined actions of both drugs precipitates **seizure** activity.

ANESTHESIA WITH RESPIRATORY DISEASES

- Halothane, enflurane or sevoflurane are drugs of choice as induction agents in children because they have a bronchodilator effect.
- Isoflurane or desflurane produce the same bronchodilator effect, but they must be increased slowly with care because they exert a mild irritant effect on the airways.
- **Succinylcholine:** Although it produces marked histamine release, it is used safely in asthmatic patients.

To blunt reflex bronchospasm induced by intubation:

1. Additional dose of thiopentone 1-2 mg/Kg.
 2. Ventilating with 2-3 MAC volatile agent for 5 min.
 3. Lidocaine - I.v. 1-2 mg/kg 1-2 min before intubation.
 - Intra-tracheal 1-2 mg/kg just before intubation but it can induce bronchospasm if an inadequate induction dose of thiopentone is used.
 - Spray over the larynx and trachea just before intubation.
- To assess intubation: by - Capnography.
 - Auscultation (may be difficult if there is marked bronchospasm)

- **LMA is a very suitable choice because it decreases bronchospasm when compared to E.T.T.**

Maintenance:

Volatile Anesthetics \pm N₂O + Muscle Relaxant + Controlled Ventilation

Volatile anesthetics:

- They are the most suitable due to their potent bronchodilating effect (sevoflurane has the same bronchodilator effect as halothane).
 - It is more important to achieve depth of anesthesia rather than the agent.
- In elderly COPD, asthmatic patients or cardiac patients who can not tolerate the depth of anesthesia, lidocaine infusion 1-2 mg/kg/hr is used.
- Avoid halothane as it sensitizes the heart to aminophylline and β_2 agonists (other agents do not sensitize the heart).

N₂O: It is used with care. It should be avoided in patients with;

- Large bullae which may rupture and cause tension pneumothorax.
- Pulmonary hypertension which may be increased and cause pulmonary edema.

Muscle Relaxants:

- Pancuronium, vecuronium, cis-atracurium and rocuronium are drugs of choice.
- Avoid d-tubocurarine and others which cause histamine release.
- Although atracurium produces histamine release, it can be used safely in most asthmatic patients especially if given slowly.

Controlled Ventilation:

- With warmed, humidified gases whenever possible.
- Adjust ventilation parameters as follows;
 1. Tidal volume: 10-15 mL/Kg slightly more than normal
→ to allow optimal ventilation/perfusion matching.
 2. Respiratory rate: 8-10 breath/min slightly less than normal
→ to allow sufficient time for venous return to the heart.
 3. Relatively long expiratory time i.e. I: E ratio to be > 1 : 2 (up to 1 : 3):
→ to avoid air trapping in the lung.

Intraoperative Fluid:

It should be **generous** to maintain adequate hydration. It causes less viscid secretions to be easily expelled from the airway.

Intraoperative Complications:**Intraoperative Bronchospasm****Cause:**

- Light anesthesia (straining) or traction on viscera causing vagal stimulation.
- E.T.T: • Touching carina.
 - Endobronchial intubations.
 - Tube obstruction e.g. over-inflation of the balloon, kinking, secretions.
- Lung: • Aspiration • Pneumothorax. • Pulmonary edema • Pulmonary embolism.
- Drugs: • Ether • Trichloroethylene (irritant).
- A patient in acute asthmatic attack.

Manifested by:

- Wheezes.
- Slowly rising wave on capnography, the severity of obstruction is generally inversely related to the rate of rise in the end-tidal CO_2 (figure 8-10).
- Increased peak inspiratory pressure.
- Incomplete expiration (i.e. decreased expiratory tidal volume).

N.B.; Auto-PEEP (Air Trapping):

It occurs in asthmatic patients with increased airway resistance with short expiratory time. Therefore, not enough time for expiration is present causing air trapping which causes more increase in airway pressure. This decreases VR especially in marginal volume status patients producing hypotension.

Management:

1. Assess the cause of bronchospasm.
2. Increase the depth of anesthesia by volatile agents (after measuring BP).
3. Mild bronchospasm treated by a β_2 agonist aerosol put into the inspiratory limb of the breathing circuit.
4. Moderate to severe bronchospasm is treated by;
 - Aminophylline i.v. slowly, with ECG monitoring. It causes dysrhythmia especially with halothane.
- If the patient was not receiving preoperative aminophylline, give a 6 mg/kg bolus over 20 min followed by 0.5-0.9 mg/kg/hr.
- If the patient was receiving preoperative aminophylline give $\frac{1}{4}$ - $\frac{1}{2}$ the previous doses according to aminophylline plasma level.

N.B.; General anesthesia decreases hepatic blood flow by 30 % so, it is advisable to decrease the rate of infusion of aminophylline by 30 % to compensate for the decrease in its metabolism.

- β_2 agonist as - Terbutaline s.c. 0.25 mg or metered inhaler aerosol.
 - Salbutamol nebulizer by +ve pressure ventilation
- or i.v. slowly 125-250 μg with ECG monitoring.
- Hydrocortisone i.v. 100-200 mg.
- Ketamine i.v.
- 5. Finally, if there is still severe spasm, use ICU ventilator which can provide high inspiratory pressure (in front of high airway resistance) e.g. 120 cm H_2O but, inhalational agents can not be used so, change to TIVA. Recently, **Siemens 900 D** anesthesia machine incorporates an ICU-type ventilator with a vaporizer and O_2 mixer

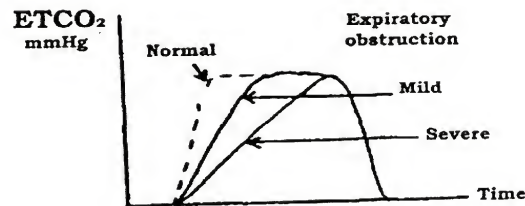


Figure 8-10; Capnograph of airway obstruction

ANESTHESIA WITH RESPIRATORY DISEASES**Recovery:**

- Deep extubation, before airway reflexes return, decreases the risk of bronchospasm.
- If awake extubation is indicated, lidocaine 1-2 mg/Kg i.v or 1-2 mg/Kg/hr i.v. infusion is given to decrease airway reflexes.

Postoperative Management:

Close respiratory monitoring. Patients with severe disease should be managed in ICU

1. Humidified Oxygenation:

In asthmatic patients, there is no hypoxic drive or CO₂ retention so, high inspired O₂ can be tolerated monitored by pulse oximetry.

2. Position: Semi-setting and sitting upright in a chair as soon as possible**3. Elective Postoperative Controlled Ventilation** is rarely needed

Indication: • PaCO₂ > 50 mm Hg.

• PaO₂ < 50 mm Hg + dyspnea at rest.

• Pulmonary function tests are < 50 % of predicted.

4. Adequate Analgesia:

By; - Simple non-opioids analgesics as non-steroidal anti-inflammatory drugs (NSAIDs). Care should be taken with NSAIDs because they can cause bronchial asthma.

- Opioid analgesics • Better to be avoided and if used, it should be under supervision.

• Pethidine is preferred than morphine.

• Patient controlled analgesia.

- Local or regional techniques.

- Transcutaneous Electrical Nerve Stimulation (TENS)

Value: Pain may compromise respiration especially after abdominal or thoracic surgery.

5. Continue Treatment Postoperatively as bronchodilators, antibiotics, physiotherapy.**Chronic Obstructive Pulmonary Disease (COPD)****Pathogenesis:**

It is classified into a chronic bronchitic group and an emphysematous group representing the two extremes, but most patients are in between with mixed features.

	Chronic Bronchitis (Blue Bloater Syndrome)	Emphysema (Pink Puffer Syndrome)
Cause	<ul style="list-style-type: none"> - Smoking (the commonest) - Air pollutants - Recurrent chest infection 	<ul style="list-style-type: none"> - Smoking (the commonest) - Homozygous α_1 anti-trypsin deficiency α_1 antitrypsin is a protease inhibitor that prevents the proteolytic activity of enzymes (mainly elastase in the lungs, these enzymes are produced by pulmonary neutrophils and macrophages in response to infection and pollutants).
Pathology	<ul style="list-style-type: none"> - Chronic irritation causes; • Bronchospasm [the term chronic asthmatic bronchitis is used when bronchospasm is a major feature]. • Hypertrophy of bronchial mucous glands with increased secretions. • Inflammation with bronchial edema causes airway obstruction [increased airway resistance]. 1st it is reversible then becomes irreversible (elastic recoil is normal) - When CO₂ retention occurs, the normal ventilatory drive becomes mainly 	<ul style="list-style-type: none"> - There is; • Destruction of alveolar septa which causes irreversible enlargement of the airways distal to the terminal bronchioles. • Loss of elastic recoil (that normally supports small airways by radial traction). This causes premature collapse during expiration. • Destruction of pulmonary capillaries in alveolar septa which decreases the diffusion capacity and causes pulmonary hypertension. Cor pulmonale occurs later

	dependent on the hypoxic drive. - Hypoxia causes early cor pulmonale.	(normal airway resistance).
C/P - Cough - Dyspnea - Sputum - Cor pulmonale	- Productive cough on most days of 3 consecutive months for at least 2 consecutive years - Little and mild - Copious - Early	- With exertion - Marked, patients often purse their lips to delay closure of small airways, hence the name - Scant - Late
Investigation - Hct - PaCO ₂ (mm Hg) - PaO ₂ (mm Hg) - Chest X-ray	Due to hypoxia and hypercapnia - ↑ - ↑ > 40 - ↓ < 60 - ↑ lung vascular markings due to inflammation	Due to dyspnea - Normal - Normal or ↓ < 40 - Normal or ↑ > 60 - Picture of emphysema as hyperinflation ..etc.
Prognosis	Poor	Good

Preoperative Management:

The same as bronchial asthma.....

Intraoperative Management:**A. Regional Anesthesia:**

The same as bronchial asthma.....

+ For brachial plexus blockade, the axillary route is preferred to avoid possible pneumothorax which is associated with the supra-clavicular route and phrenic nerve blockade with interscalene approach because the chest is emphysematous.

B. General Anesthesia

The same as bronchial asthma.....

Postoperative Management:

Close respiratory monitoring is essential. Patients with severe disease should be managed in ICU.

1. Humidified Oxygenation:

If the patient has CO₂ retention and a hypoxic drive, the patient can not tolerate high inspired O₂. So, the aim is to maintain;

- SaO₂ > 90 % and PaO₂ = 60-80 mm Hg.
- PaCO₂ = < 55-60 mm Hg and pH 7.35-7.45.

Frequent monitoring with pulse oximetry and arterial blood gases are essential.

Therefore, FiO₂ is titrated either by;

- Venturi mask, usually at 24-28 % (1-2 L/min).
- Mechanical ventilation.

2. Position: Semi-setting and sitting upright in a chair as soon as possible.

3. Elective Postoperative Controlled Ventilation:

The same as bronchial asthma.....

4. Adequate Analgesia

5. Continue Treatment Postoperatively: The same as bronchial asthma.....

6. Breathing Exercise (Inspiratory Exercise):

- It is either;
- Voluntary deep breathing.

ANESTHESIA WITH RESPIRATORY DISEASES

- Incentive spirometry: It is a type of voluntary deep breathing in which the patient is given inspired volumes as a goal to achieve.

Both cause re-expansion of collapsed alveoli.

N.B.; Expiratory Maneuvers:

As inflating balloons, the use of blow bottles or performing FVC are not recommended because they make patients exhale below the FRC which generates pleural pressure that exceeds airway pressure and causes collapse of alveoli.

7. Continuous Positive Airway Pressure (CPAP):

By either - Nasal CPAP.

Or - Close fitting facemask.

In a spontaneously breathing patient, CPAP increases the FRC and decreases atelectasis therefore, it decreases the need for IPPV.

8. Mini-Tracheostomy:

- Percutaneous crico-thyroid puncture and insertion of a small diameter tube into the trachea is done. This allows aspiration of secretions and preserves the ability to cough and speak. It is very rarely needed.

Restrictive Pulmonary Diseases:

A. Acute Intrinsic Restrictive Lung Diseases (Pulmonary Edema):

(↑ EC lung water).

a. Cardiogenic pulmonary edema: congestive heart failure (high pressure pulmonary edema).

b. Non-cardiogenic pulmonary edema (low pressure pulmonary edema):

1. Adult respiratory distress syndrome.
2. Aspiration pneumonitis.
3. Neurogenic pulmonary edema.
4. High altitude pulmonary edema.
5. Negative pressure pulmonary edema.

B. Chronic Intrinsic Restrictive Lung Diseases (Interstitial Lung Disease):

(↑ lung fibrosis).

- Sarcoidosis.
- Pulmonary alveolar proteinosis.
- Diffuse idiopathic pulmonary fibrosis.
- Drug induced pulmonary fibrosis as bleomycin, methotrexate, busulphan....
- Radiation pneumonitis.

C. Chronic Extrinsic Restrictive Lung Diseases: (Decreased lung expansion).

a) Disorders of the chest wall:

- Obesity.
- Flail chest e.g. parallel vertical multiple rib fracture or separation of a median sternotomy after cardiac surgery.
- Deformity of the sternum as pectus excavatum.
- Kyphoscoliosis.
- Ankylosing spondylitis.

b) Increased intra-abdominal pressure:

- Ascitis.
- Pregnancy.

c) Neuromuscular disorders:

- Spinal cord transection.
- Guillian Barré syndrome.
- Myasthenia gravis.
- Eaton-Lambert syndrome.

- Muscular dystrophies.

D. Disorders of the Pleura and Mediastinum: (Decreased lung expansion).

- Pleural effusion or fibrosis.
- Pneumothorax.
- Mediastinal mass
- Pneumo-mediastinum.

Pathology:

Group A increased extra-vascular lung water.

Group B causes lung fibrosis.

Groups C and D cause interference with lung expansion.

So; all decrease lung compliance resulting in increased work of breathing causing;

- Dyspnea (acute or chronic on exertion or at rest).
- Rapid shallow breathing causing normal or decreased PaCO_2 .
- Hypoxia.

Destruction of pulmonary vasculature in chronic restrictive lung diseases causes pulmonary hypertension and cor pulmonale.

Anesthetic Management:

Preoperative Management:

Preoperative Evaluation:

- C/P of restrictive lung disease.
- Assess the cause of restrictive lung disease and its treatment.
- Preoperative investigationsee before.

Preoperative Patient Preparationsee before.

Intra-operative Management

A. Regional Anesthesia:

Avoid a high sensory level above T_{10} to maintain acceptable ventilation.

B. General Anesthesia:

- Induction:
- Maintenance:I.v and inhalational agents can be used safely.
- IPPV with care for;
 - Tidal volume: 8-10 mL/Kg (slightly less than normal)
 - Respiratory rate: 14-18 breath/min (slightly more than normal).
 - Peak airway pressure: should not be increased $> 40 \text{ cm H}_2\text{O}$ due to decreased lung compliance as it may increase the risk of barotrauma.
 - PEEP : may be required.

Postoperative Management

Elective controlled ventilation may be needed.

Pulmonary Edema

Definition:

It is transudation of fluid first from pulmonary capillaries into the interstitial space and then from the interstitial space into the alveoli due to either:

- Increased pulmonary capillary pressure (high pressure pulmonary edema)
 - i.e. cardiogenic pulmonary edema.
- Or - Increased pulmonary capillary permeability (low pressure pulmonary edema)
 - i.e. non-cardiogenic pulmonary edema.

I. Cardiogenic (Hemodynamic) Pulmonary Edema

Causes:

1. Pulmonary venous hypertension (congestion) due to
 - MS
 - LVF
 - LA obstruction.
 2. Marked increase in pulmonary blood flow due to:
 - Left to right cardiac shunt
 - Severe anemia.
 - Hypervolemia.
 - Severe exercise.
-See C.V.S. for more details.

II. Non-Cardiogenic Pulmonary Edema

Acute Respiratory Distress Syndrome (ARDS)

Definition: (By 1994 Consensus).

It is a clinical syndrome characterized by a pulmonary disorder resulting from diffuse injury to the alveolo-capillary membranes. It represents the pulmonary manifestation of a pan-endothelial insult due to a systemic inflammatory response syndrome (SIRS).

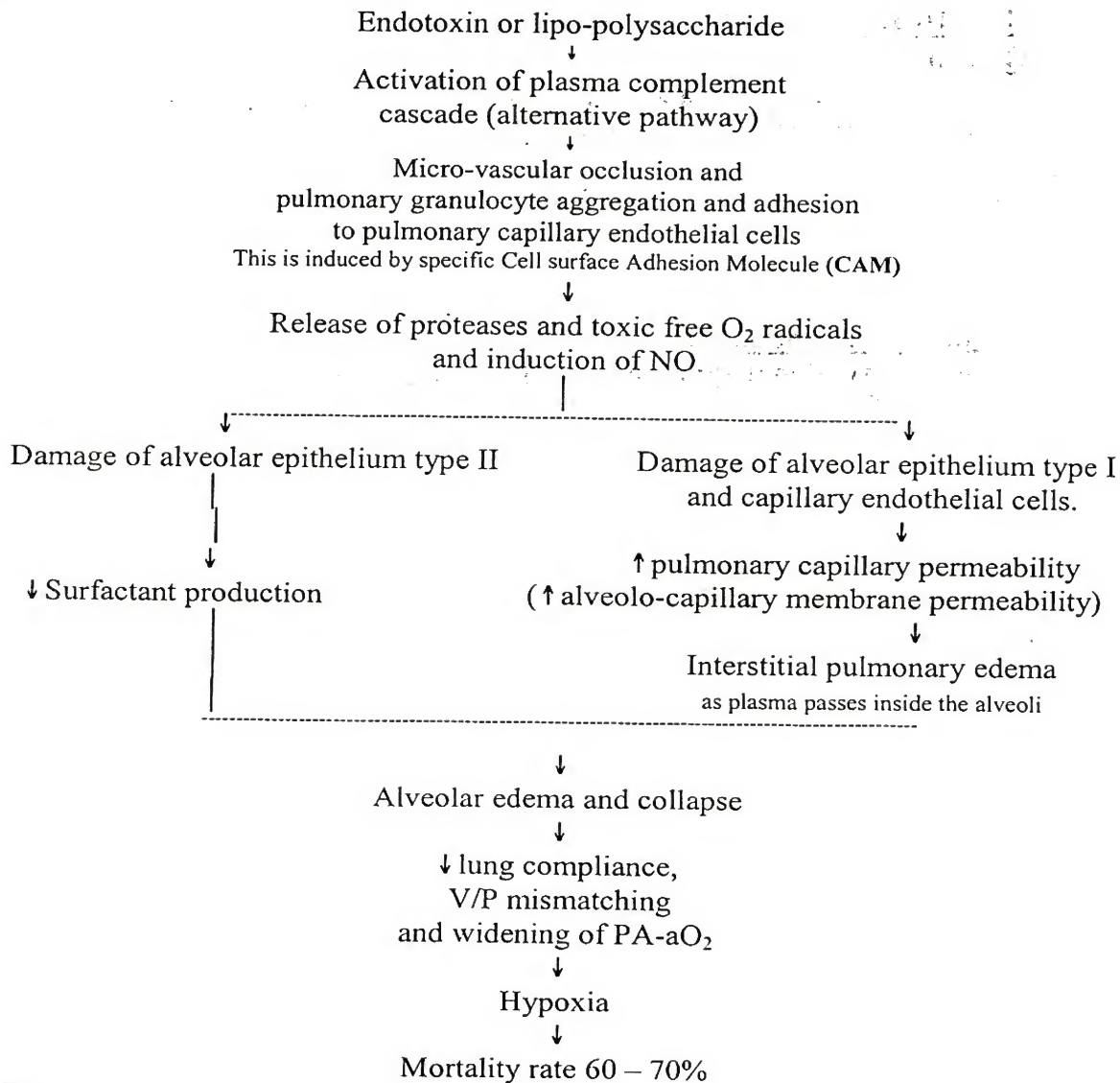
Criteria of ARDS:

- a) Bedside findings of tachypnea, dyspnea and crackles.
 - b) Decreased compliance < 40 cc/ cm H₂O.
 - c) Decreased gas exchange ($\text{PaO}_2/\text{FiO}_2 < 200$)
N.B.; Acute lung injury: $\text{PaO}_2/\text{FiO}_2 = < 300$ mm Hg.
 - d) Diffuse (3 or 4 quadrant) airspace infiltrates on chest radiograph.
 - e) Exclusion of high pressure pulmonary edema (cardiogenic pulmonary edema).
- At a consensus conference, (acute) rather than (adult) was agreed to be the preferred terminology because the same picture is also seen in children.
- It was previously called - Post-traumatic pulmonary insufficiency syndrome.
- Shock lung syndrome.
 - Wet lung syndrome.
- Or - Stiff lung syndrome.

	Pulmonary (Direct, primary) ARDs	Extra-Pulmonary (Indirect, secondary) ARDs
Causes	1. Aspiration pneumonitis. 2. Near drowning. 3. Severe pneumonia (bacterial, viral, protozoal). 4. Lung contusion or chest trauma. 5. Blast injury. 6. Post-pneumonectomy. 7. Thoracic irradiation. 8. Smoke or toxic gas inhalation. 9. O ₂ toxicity.	1. Multiple trauma, head injury, or massive burn. 2. Circulatory shock. 3. Septicemia (especially gram-ve). 4. Multi-organ dysfunction syndrome. 5. Massive blood transfusion. 6. Fat embolism. 7. Amniotic fluid embolism. 8. Heroin overdose. 9. Pancreatitis (release of proteinase and lipase cause damage of the pulmonary capillary endothelium). 10. Disseminated intravascular coagulation (DIC). 11. Malaria. 12. Poisoning (drug induced) as salicylates, amiodarone, busulphan, or bleomycin. 13. Post-cardiopulmonary bypass. These are the causes of SIRS.

Pathogenesis:

- a. ARDS represents the pulmonary manifestation of a systemic inflammatory response syndrome which includes release of large amounts of **cytokines** and other 2ry mediators like tumor necrosis factor, interleukin 1, 2, 6, and 8, platelet activation factors and various PGs, **nitric oxide (NO)**, **endothelin** and leukotrienes. These increase capillary permeability all over the body.
- b. Activation of the plasma complement cascade.

**C/P:**

- Of the cause ... 5- 10 % the cause may be unrecognized.
- Progressive dyspnea, tachypnea, cyanosis up to respiratory failure.
- Progressive tachycardia, cardiac dysrhythmias and hypotension.
- Multi-organ dysfunction syndrome (MODS):
 - It occurs in critically ill or injured patients.
 - There is a hyperdynamic and hyper-metabolic state (similar to sepsis).
 - The sequence of organ failure in most patients is as follows; the lung (the 1st organ to fail), the liver, the kidney, GIT mucosa (it losses its barrier against luminal bacteria),

ANESTHESIA WITH RESPIRATORY DISEASES

the heart (ventricular wall motion abnormalities despite of increased CO), and lastly CNS dysfunction occurs. Death is the fate in 100 % of cases if more than 3 organs fail.

Investigation:

1. Arterial blood gases: severe hypoxemia.
2. Chest X-ray: Bilateral interstitial pulmonary infiltrates which may progress to complete opacification (whiteout).
3. Pulmonary artery catheter.
 - PCWP is normal or decreased unless there is CHF.
 - PAP may show pulmonary hypertension due to obliteration of capillaries by fibrotic changes.

Management: In ICU**I. O₂ Therapy:**

- Initially PaO₂ can be maintained while PaCO₂ is decreased, but when ARDS worsens, even 100 % O₂ may not prevent hypoxemia and hypercapnia.

II. Inotropes:

- Dopamine or dobutamine is used according to C.V.S. status.

III. Diuretics And Restriction of I.v. Fluid Administration:

- To decrease pulmonary edema, but this may make the patient dehydrated. So, care is taken if anesthesia is given to these patients.

IV. Ventilation Management:

- **In the past a conventional approach** was used. It includes;
 - A tidal volume of 12 mL/Kg.
 - Selection of the lowest PEEP to achieve adequate oxygenation.
 - Keeping the PaCO₂ between 35-38 mm Hg.
- **Recently**, ventilatory management of patients with ARDS have been changed from the conventional approach to the **lung protection strategy** due to the following causes;

Ventilator Induced Lung Injury:

- 1- **Acute lung injury occurs at low lung volumes below LIP** (see before in respiratory physiology) because at the lower volumes (below functional residual capacity "FRC"), cyclic opening and closure of alveolar units during tidal breathing may lead to **lung injury from generated shear forces**. The regions most subjected to this type of injury are at the interface between lung units that are edematous and non-functioning, and regions that are recruitable and mildly affected by the ARDS process.
- 2- Acute lung injury occurs also **at high lung volumes above UIP** because high airway pressure can cause **segmental alveolar over-distention**.
- 3- **Barotrauma-induced lung injury**.
(See static pressure-volume curve).

Therefore, **the Lung Protective Strategy** (Lung Protection) is done.

Value:

There is improvement in survival rates in ARDS patients and less systemic inflammatory processes are associated.

It includes the following considerations:

- 1- Maintenance of **lower peak inspiratory pressures (PIP)** (< 20 cm H₂O above PEEP).
- 2- Use of **lower tidal volume (6 mL/Kg)**.
- 3- **Use of PEEP maintained above the lower inflection point** on the static pressure-volume curve of the respiratory system to allow circumvention of alveolar collapse.
- 4- **Liberal sedation** is used to improve patient-ventilator synchronization.
- 5- **Permissive hypercapnia:**

The ventilation parameters are adjusted as;

- Low tidal volume, to prevent peak airway pressure exceeding 40 cm H₂O.
- Low respiratory rate, to provide pulmonary rest allowing good oxygenation.

But both **increase PaCO₂** which is allowed to **increase up to 20-40 mm Hg above the baseline.**

When pH becomes < 7.2 i.e. severe respiratory acidosis, HCO₃⁻ is used.

This technique is **contraindicated** in patients with **increased ICT** and **cautiously used** in patients with **ischemic heart disease or severe LV dysfunction.**

Ventilatory modes used in lung protective strategy:

a- Synchronized Intermittent Mandatory Ventilation (SIMV):

- It is used with a reduced tidal volume (6 mL/Kg)

b- Pressure Support Ventilation:

c- Biphasic Positive Airway Pressure (BiPAP):

In which 2 different pressure levels are installed which alternate periodically.

d- Pressure Controlled Ventilation with a Small PEEP:

e- Inverse Ratio Ventilation:

It is reversal of the normal I: E ratio to be more than 1: 1, usually 2: 1 is selected.

These modes are not used during anesthesia for a patient with ARDS.

Adjuvant Therapy With Ventilation used in ARDS Patients:

A- Prone Ventilation:

- Recently, it was found that ventilation in the prone position improves oxygenation. This usually takes several hours to occur, but when the patient returns to the supine position, desaturation occurs in minutes.
- This method is not used except if other methods fail to increase O₂ in the supine position.

B- Trans-Tracheal Gas Insufflation:

- It has been tried in some ARDS patients.

C- Extra-Corporeal Membrane Oxygenator (ECMO): "see later".

D- Liquid Ventilation: "see later".

V. Pharmacologic Management:

1. Corticosteroids:

- They have no role in prevention or initial treatment of ARDS.
- In the fibrotic stage, they can decrease inflammation in the lungs and improve oxygenation

2. Surfactant:

- The role of exogenous surfactant therapy is still being evaluated.

3. Nitric Oxide (NO):

Inhalation of NO in doses up to 2 parts per million (ppm) in respiratory failure can produce dose-dependent selective pulmonary VD without causing systemic VD, reduce intrapulmonary shunts and improve PaO₂.

4. Prostacyclin:

Short term infusion is used to produce pulmonary VD, so it can be used to treat pulmonary hypertension.

5. Activated Protein C:

It has been tried with good results in ARDS and sepsis.

N.B.; Infant Respiratory Distress Syndrome.

.....See later, pediatric anesthesia.

Q: Discuss recent ventilatory management of ARDS ?

A: As above.

Q: What is pediatric ARDS ?

A: Discuss • Acute (adult) respiratory distress syndrome.

- Infant respiratory distress syndrome.

Aspiration Pneumonitis

Causes of Perioperative Aspiration:

- 1- High ASA physical status and unconscious patient.
- 2- An emergency operation.
- 3- Difficult airway management.
- 4- Predisposing (risk) factors which include;
 1. Upper GIT bleeding.
 2. Decreased tone of the lower esophageal sphincter e.g. pregnancy, obesity, drugs, or naso-gastric tubes.
 3. Gastro-esophageal reflux or esophageal strictures.
 4. Increased volume and/or acidity of gastric contents.
 5. Increased intra-gastric pressure e.g. lithotomy position.
 6. **Delayed gastric emptying:**
 - a- Physiologic causes: pain, anxiety, pregnancy (in some patients).
 - b- Pathologic causes:
 - Acute gastro-paresis as gastroenteritis, ketoacidosis, electrolyte imbalance, hypercalcemia or migraine.
 - GIT obstruction.
 - Diabetes (for solids, but not liquids).
 - Polymyositis or dermatomyositis.
 - Systemic sclerosis.
 - c- Pharmacologic:
 - Opioids.
 - Anticholinergics as atropine, hyoscine, anti-histaminics, phenothiazines and tricyclic antidepressant.
 - Sympathomimetics as isoprenaline and salbutamol.
 - Dopamine.
 - Nefopam.
 - Alcohol.
 7. Gastric outlet obstruction (pyloric obstruction).
 8. Small or large intestinal obstruction.

N.B.; Although the clinical impression is that obesity causes delayed gastric emptying, there has been evidence that obesity is associated with accelerated gastric emptying of liquids and solids.

Pathology of Aspiration Pneumonitis:

Injury from aspiration occurs by 3 mechanisms:

- 1- **Mechanical obstruction** by particulate matter: It causes atelectasis resulting in an intrapulmonary shunt which increases the alveolar-arterial O_2 gradient (i.e. $\uparrow A-a DO_2$). This causes arterial hypoxemia.
- 2- **Chemical pneumonitis** by the acidic gastric fluid (when its pH is < 2.5): It causes destruction of pneumocytes type I and II (decreasing surfactant) and capillary endothelium resulting in atelectasis. Some authors refer to this pathology as **aspiration pneumonitis**.
- 3- **Bacterial pneumonitis** by bacterial contamination. Some authors refer to this pathology as **aspiration pneumonia**.

All cause picture of ARDS.

C/P:

- The earliest and most reliable sign is **hypoxemia** refractory to O_2 therapy.

- **Aspirated volume** > 25 mL (0.4 mL/Kg).

It may cause aspiration pneumonitis.

• **Aspirated particulate (solid) matter:**

It may cause respiratory obstruction at any level.

Patients of both groups can show:

- Acute effects as immediate acute respiratory distress, cyanosis, dysrhythmias and cardiac arrest.
- Chronic effects occur after 6-8 hrs, with a mild chronic course of aspiration pneumonitis and lung abscess (stagnant secretions + bacterial infections e.g. E. coli, pseudomonas, Klebsiella, anaerobes, staphylococci or bacteroids).

• **Aspirated material with pH < 2.5 will cause Mendelson's Syndrome:**

- It is acute chemical aspiration pneumonitis 1st described by Mendelson in 1946.
- It is due to the irritative action of gastric HCl which causes bronchiolar spasm, and peri-bronchiolar exudates, as well as its congestive action.
- It is characterized by a tri-phasic sequence of clinical events:
 - a- A phase of immediate respiratory distress: dyspnea, tachypnea, tachycardia, cyanosis, bronchospasm, pulmonary edema, CHF up to cardiac arrest.
 - b- A phase of partial recovery.
 - c- A phase of gradual return of respiratory dysfunction: picture resembling ARDS.

Investigation:

1. Chest X-ray:

Patchy pneumonitis appears as patchy irregular densities (fluffiness or whiteout) especially in the right lower lobes. It occurs after 6-12 hours.

2. Arterial Blood Gases:

Hypoxemia appears.

Management:

It is better to prevent aspiration pneumonitis than to treat it.

I - Prevention:

1. Measures to Decrease Gastric Fluid Volume:

a) For Elective Surgery (Preoperative NPO)

ASA recommendations (It applies only to healthy patients for elective surgery. It is not applied to women in labor).

Type	Minimum Fasting Hours (for all ages)
- Clear fluids (water, fruit juices without pulp, carbonated beverages, clear tea, black coffee)	2 hrs As this ↓ gastric contents & acidity compared to preparative fasting.
- Breast milk	4 hrs
- Infant formula.	6 hrs
- Non-human milk.	6 hrs
- Light meals (toast and clear fluids).	6- 8 hrs
- Solid.	8 hrs.
- Oral medications.	1-2 hrs with up to 150 ml of water.

N.B.; Preoperative fasting does not ensure an empty stomach. It was found that 12-80 % of patients scheduled for an elective surgery have a gastric volume of > 0.4 mL/Kg and a pH of < 2.5.

b) For Emergency Surgery:

- Empty the stomach by physical means:
 - A large bore **naso-gastric tube** which is withdrawn before induction of GA.
- Empty the stomach by pharmacologic means:
 - **Metoclopramide** (plasil) 10 mg i.v/i.m 1-2 hrs before induction of GA.
- Suppress gastric secretions:
 - **Cimetidine** 300 mg i.v/i.m 1-2 hrs, before induction of GA.
 - or • **Ranitidine** 50 mg i.v/ 150 mg i.m 1-2 hrs, before induction of GA.

ANESTHESIA WITH RESPIRATORY DISEASES**2. Measures to Decrease Gastric Acidity:****a. Neutralize The Existing Acid:**

By non-particulate antacids e.g. Na citrate (15-30 mL of 0.3 molar solution, 15-30 minutes before induction of GA) or Na HCO₃.

b. Suppress New Gastric Acid Secretion:

By H₂- receptor antagonists. They increase the gastric pH to > 2.5 in 80 % of patients.

- Cimetidine: 300 mg i.v/i.m, 1-2 hrs before induction of GA.

- Ranitidine: 50 mg i.v/ 150 mg i.m, 1-2 hrs before induction of GA.

- No single agent or combination has been shown to give optimum intra-gastric conditions indicative of complete protection.

3. Measures to Prevent Regurgitation:**a. Increase The Tone of The Lower Esophageal Sphincter:**

- Metoclopramide 10 mg i.v/i.m, 3 min before induction of GA.

- **Avoid drugs that decrease the tone of the sphincter** e.g. atropine, opioids, benzodiazepines before induction of anesthesia.

b. Avoid Increased Intra-gastric Pressure:

- **Avoid +ve pressure ventilation** before intubation.

4. Measures to Prevent Aspiration if Regurgitation Occurs:**a. Rapid-sequence induction (crash induction).****b. Induction in the lateral position with a head down tilt.****c. Cricoid pressure (sellik's maneuver).**

- From the beginning of induction till inflation of the ETT's cuff.

- The efficacy and safety of cricoid pressure has been questioned. (It is the most important by some authors).

d. Powerful suction machine.**e. Cuffed E.T.T.****5. Be Aware of Intubation Difficulties.****6. Awake Intubation.****7. Regional Anesthesia.****II - Treatment:**

If aspiration of gastric contents occurs, the following measures must be carried out immediately:

1. Position: - Lateral position with head down tilt (to 30 degrees).

2. Oro-Pharyngeal Suctioning: It is done under vision by laryngoscope.

3. Prompt Endotracheal Intubation With Cuffed ETT: to prevent further aspiration.

4. Suction Through The E.T.T.:

- This should be done before administration of 100 % O₂ by +ve pressure ventilation to prevent further pushing of the aspirated material beyond reach.

- Suction should be brief to avoid cardiac arrest from hypoxemia.

- **Tracheo-bronchial aspirate** should be collected for **culture and sensitivity** tests.

- O₂ 100 % should be given after suction.

- Tracheo-bronchial lavage.

5. Bronchoscopy:

- Indications: - Particulate matter in the aspirate.

- Signs of obstructive atelectasis.

6. Ventilatory Support: IMV ± PEEP.

7. Restoration of the Intravascular Volume:

Especially by **albumin solutions** because hypo-albuminemia occurs due to extravasation of protein containing fluid into the lungs.

8. Bronchodilators:

to relieve bronchospasm.

9. Corticosteroids: Its use is controversial

Dose: - Methyl prednisolone 30 mg/kg i.v.

Or- Dexamethazone 1 mg/kg i.v.

- Advantages:

1. They decrease the inflammatory process.
2. They decrease pulmonary cellular damage and protecting type II alveolar pneumocytes by stabilization of lysosomal membranes.
3. They decrease agglutination of platelets and leukocytes.
4. They decrease pulmonary H₂O content.

10. Prophylactic Antibiotics.**11. Monitoring and Further Investigations:**

- Measurement of the **gastric fluid pH** is useful because it reflects the pH of the aspirated fluid.

N.B.; Measurement of the tracheal aspirate pH is of doubtful value because inhaled gastric fluid is likely to be rapidly diluted by airway secretions.

- **Frequent arterial blood gases analysis.**

- **Hemodynamic monitoring;**

1. Arterial line: for continuous invasive ABP monitoring.
2. Pulmonary artery catheter: for measurement of PCWP, CO, PVR, and SVR.

Other Forms of Non-Cardiogenic Pulmonary Edema

	Neurogenic Pulmonary Edema	High Altitude Pulmonary Edema	Negative Pressure Pulmonary Edema
Cause	- Brain injury producing severe sympathetic stimulation which results in generalized VC. This shifts blood volume from the systemic to the pulmonary circulation causing pulmonary edema usually after hours from brain injury.	- High altitudes cause sustained alveolar hypoxia. This results in hypoxic pulmonary VC which increases the pulmonary vascular pressure producing pulmonary edema.	- Acute upper airway obstruction e.g. laryngospasm then on sudden relief of the obstruction or sudden re-expansion of the collapsed lung, -ve intra-pleural (intra-thoracic) pressure occurs causing pulmonary edema because; <ul style="list-style-type: none"> • During inspiration, complete obstruction causes high -ve pressure which causes transudation into the alveoli (Müller maneuver). • During expiration, decrease in VR occurs so, on relief of obstruction, VR increases causing extravasation of fluid.
Treatment	- Decrease ICT. - O ₂ ± PEEP. - Ventilation.	- Descend to near sea level. - O ₂ ± PEEP. - Nifedipine: It causes pulmonary VD. - A portable hyperbaric chamber can be used for rapid simulation of descent.	- It usually resolves spontaneously - O ₂ ± PEEP - Diuretics

Disorders of the Pleura and Mediastinum

I. Pneumothorax:

Definition: Presence of gas within the pleural space.

Causes:

a. Spontaneous:

- Idiopathic.
- Congenital bullae.
- Marfan syndrome.
- Generalized emphysema.
- Bronchial asthma.
- Rapid decompression of divers.

b. Traumatic:

- External penetrating chest injury causing disruption of the parietal pleura.
- A tear in lung parenchyma causing disruption of the visceral pleura.
- Rib-fracture causing disruption of one of them.

c. Iatrogenic:

- Cervical or thoracic surgery.
- Brachial plexus blockade.
- Cannulas of subclavian or internal jugular veins.
- Inadvertent barotrauma.

C/P: Ipsilateral collapse of the lung causing V/Q mismatching:

- Sudden severe chest pain, dyspnea, and hyper-resonance on percussion of the chest.
- During anesthesia;
- Decreased or absent breath sounds.
 - Unexplained bronchospasm, altered pattern of breathing.
 - Unexplained tachycardia, hypotension.
 - Arterial hypoxemia causing cyanosis and sudden decrease in the pulse oximetry reading.

Investigation:

Chest X-ray; before induction of anesthesia is important if there is chest trauma.

Management:

- Spontaneous pneumothorax (asymptomatic and < 20% of lung has collapsed): It spontaneously resolves, but only give O₂.
- Stop N₂O and give 100 % O₂ with +ve pressure ventilation immediately.
- Chest tube with underwater seal in the 4th or 5th intercostal space anterior to the mid-axillary line.
- For resistance cases; surgical intervention is needed.

Tension Pneumothorax

Definition:

It develops when gas enters the pleural space during inspiration and is prevented from escaping during expiration. This causes progressive increase in the amount of air trapped under increasing pressure (tension).

Causes: The same as pneumothorax.

C/P: The same as pneumothorax.

But, • more severe up to shock.

- Mediastinal compression with tracheal shift to the normal side.

Treatment:

- Emergency treatment: Needle aspiration or i.v. cannula (gauge 14, 3-6 cm long) insertion in the mid-clavicular line into the 2nd intercostal space with underwater seal to relieve tension. It converts tension pneumothorax to open pneumothorax.
- Then chest tube placement done as above.

III. Mediastinal Masses:**Causes:**

- 1- Retro-sternal goiter.
- 2- Tumors as lymphomas, thymomas, or teratomas.

Preoperative Management:

1. Preoperative assessment of causes.
2. Preoperative assessment of C/P.

Mediastinal masses cause compression of;

- a. The airway (and trachea): airway obstruction worsens by lying supine.
 - due to – Direct mechanical compression.
 - Mucosal edema by S.V.C. syndrome.

Proximal obstruction causes dyspnea.

Distal obstruction causes dry cough.

So **preoperative assessment of the airway** e.g. chest X-ray, CT scan, flow-volumes loops are mandatory.

- b. SVC: SVC syndrome with obstruction of venous drainage from the upper 1/2 of the body.

- Edema and venous congestion of the face, neck, upper chest and conjunctiva.
- Edema of the hypo-pharynx so suspect difficult intubations.
- Edema of the upper limbs so, i.v. line and central line are preferred in the legs.
- Evidence of increased ICT as headache, and decreased mentality.

- c. Lung: restrictive lung disease.

- d. Pulmonary artery and heart: **hypoxemia and hypotension** (decreased CO due to decreased VR by the heart and SVC compression) especially on anesthesia.

3. **At least one large bore i.v. cannula placed in the lower limb** as venous drainage from the upper limb is unreliable.

4. **Preoperative chemotherapy**: may cause complications.

5. **Preoperative radiotherapy**: difficult airway management is suspected.

Intraoperative Management:

Monitoring: Standard + invasive ABP.

Choice of Anesthesia:**a. Local Anesthesia:**

- It is the safest especially for biopsy from a peripheral lymph node (cervical or scalene).

b. General Anesthesia:

- For young and uncooperative patients.
- **Awake intubation** is preferred in cooperative patients (\pm fiberoptic).
- **Inhalational induction** then intubation for uncooperative patients by halothane or sevoflurane.
- Use **armored ETT**.
- **Avoid cough and straining** as they may increase the positive pleural pressure resulting in increased intra-thoracic pressure. This precipitates complete airway obstruction. So; the armored tube **should pass the area of compression**.
- Maintenance:

ANESTHESIA WITH RESPIRATORY DISEASES

- Maintain patient **hemodynamics**.
- IPPV can cause **severe hypotension** so, volume loading is needed.
- At the end, the patient is left intubated **until the airway obstruction is resolved** as determined by
 - The flexible bronchoscope.
 - Air leak around ETT on deflation of its cuff.

Bronchial Carcinoma:**Anesthetic Problems:**

- 1) Patients usually have
 - **Chronic bronchitis**.
 - **Infection and lung collapse** distal to the tumor.
- 2) Patients may have **myasthenic syndrome**.
- 3) Para-malignant syndrome (in Oat cell carcinoma) **secretes many hormones** especially -
ADH: Syndrome of inappropriate ADH secretion causing **dilutional hyponatremia**.
- ACTH: Cushing syndrome.

Pulmonary Embolism

Definition:

It is entry of a blood clot, fat, tumor cells, air, amniotic fluid or any foreign materials (insoluble material) into the venous system.

Causes:

- I. Venous thrombo-embolism: It mostly occurs in awake patients.
- II. Venous Air embolism: It mostly occurs in anesthetized patients.
- III. Fat embolism.
- IV. Amniotic fluid embolism.

I. Venous Thrombo-Embolism (VTE):

Deep Vein Thrombosis (DVT):**Etiology:** Risk factors

Virchow's triad for DVT (in the deep venous system of the lower limbs or the pelvis).

1- Venous Stasis:

- Direct venous compression (tourniquets).
- Position: head up position, or immobility.
- Hypovolemia, hypotension, and hypothermia.
- Low CO as in CHF or acute myocardial infarction.

2- Endothelial Damage:

- Varicose veins.
- Trauma or leg surgery.
- Drug induced irritation.

3- Hyper-coagulable Status:

- Stress of surgery releases tissue thromboplastin.
- Oral contraceptive pills (estrogen containing pills).
- Malignancy (Trousseau syndrome).
- Plasminogen activator deficiency.
- Anti-thrombin III deficiency.
- Protein C or S deficiency.

N.B.; Obesity is not a proven risk factor for DVT.

- **Common Surgeries** associated with DVT.

Generally, the risk increases in surgeries lasting > 30 min.

a. Orthopedic surgery:

- Reconstructive surgery of the **hip** and the **knee** carries the highest risk.
- More than 50 % of these patients develop postoperative DVT.
- and 3% of these patients develop fatal pulmonary embolism.
- This group of patients is the most resistant to prophylaxis.

b. General surgery: **thoracic, and abdominal.**

- More than 50 % of patients in the high risk group develop postoperative DVT. unless prophylactic measures are taken.

c. Neurosurgery: as spinal surgery.

d. Urosurgery:

- Variable risk ranges from 10 % (TURP) to 40 % (Retro-pubic prostatectomy).

e. Cancer surgery: especially colon or rectum surgery.

Patients are classified into:

- a. Low risk: Patient's age < 40 years with no other risk factors.
 - b. Moderate risk: Patient's age > 40 years and procedures > 30 min.
 - c. High risk: Recent history of DVT or pulmonary embolism.
- Extensive abdominal or pelvic surgery for malignancy.

Clinical Picture:

a. **C/P of DVT:**

- Throbbing pain, edema, skeletal muscle (calf muscles) spasm in DVT affecting the veins of the lower limbs or pelvis.
- Nearly always above knee DVT is the one which produces pulmonary embolism, while below knee DVT is very rarely to produce pulmonary embolism.

b. **C/P of Pulmonary Embolism:**

- According to the size of venous emboli reaching the lung;

1. **Acute massive pulmonary embolism:**

It involves > 50 % of the main pulmonary artery causing obstruction of PA outflow. It produces sudden circulatory collapse and death.

2. **Chronic showering of pulmonary micro-emboli:** It produces;

- Pulmonary infarctions with episodes of pleuritic chest pain and hemoptysis.
- Chronic thrombo-embolic pulmonary hypertension.
- In the elderly, multiple small pulmonary emboli may be misdiagnosed as bronchopneumonia.

The most common time for presentation of pulmonary embolism is postoperatively especially during the 2nd week. It causes;

- Sudden dyspnea and tachypnea up to irregular gasping respiration.
- Pulmonary infarction with cough, pleuritic chest pain and hemoptysis.

During anesthesia;

- Unexplained sinus tachycardia, cardiac arrhythmias, hypotension up to circulatory collapse and sudden death in massive pulmonary embolism.
- Bronchospasm.
- Arterial hypoxemia (decreased PaO₂) causing central cyanosis and an acute decrease in PaCO₂ and decreased ETCO₂ (and increased P_uCO₂).
- Increased jugular venous pressure.
- Appearance of the 4th heart sound on heart auscultation.

ANESTHESIA WITH RESPIRATORY DISEASES**Investigation:****a. For DVT:**

1. Venography shows a filling defect.

2. Fibrinogen uptake test:

A radio-labeled fibrinogen is injected **before the operation** and then a scan is done to detect incorporation of fibrinogen into the newly formed thrombus non-invasively.

Both are used as screening tests.

3. Impedance plethysmography.

4. Duplex ultrasound.

b. For Pulmonary Embolism:

1. ECG: shows signs of RV strain.

• Right axis deviation.

• Inverted T wave in leads $V_1 - V_4$.

• Right bundle branch block (RBBB).

• The classical $S_1-Q_3-T_3$ is less common.

2. Chest X-ray:

- It is sensitive in 45 % of patients, changes occur **after 2 days** from the event.

- It shows • Pulmonary oligemia (radiolucency) due to pulmonary vascular obstruction.

• Pulmonary infarction (wedge shape density).

• Pulmonary atelectasis.

• Pulmonary hypertension with enlarged proximal pulmonary artery.

3. Arterial Blood Gases:

• Decreased PaO_2 due to increased alveolar dead space.

• Decreased $PaCO_2$ due to hyperventilation.

4. Perfusion And Ventilation Lung Scans:

5. C.T. of The Chest.

6. Pulmonary Angiography (Arterio-graphy):

- It provides a definite diagnosis of major pulmonary vascular obstruction. It is **the most sensitive and specific** test.

Recently, **Digital subtraction arterio-graphy** replaces the need for direct pulmonary injection of contrast media, but it is injected intravenously.

Management:**A. Thrombo-Prophylaxis:****I. Preoperative Prophylaxis:** (in high-risk patients).

a. Correction of risk factors whenever possible.

b. Adequate hydration.

c. Leg compression stockings.

d. Leg exercise (flexion and extension of the knees, ankles and feet) should be learned by the patients preoperatively, so they can do them postoperatively.

e. Prophylactic heparin.

1. Low-dose heparin:

5000 IU s.c. every 8-12 hours is given 2 hours before surgery and continued postoperatively till the patient is ambulatory.

2. Ultra-low dose heparin:

One IU/Kg/hr i.v. infusion. This method is safe, effective and decreases discomfort and hematomas associated with the s.c. route.

3. Adjusted dose heparin:

Start with 3500 IU s.c. every 8 hours and adjust the dose to keep the activated partial thromboplastin time (APTT) at 1.5 times the control.

4. Low molecular weight heparin: e.g. Fragmin, Enoxiparin, Fraxiparin, Logiparin.

One dose is given 12 hours before surgery and continued postoperatively with one dose given every 24 hours till the patient is ambulatory.

II. Intraoperative Prophylaxis:

a. Decrease venous stasis in the lower limbs by:

- Raising the legs.
- Pneumatic leg compression.
- Avoiding leg trauma.
- Electrical calf muscle stimulation.

b. Good anesthetic and surgical techniques by:

- Adequate fluid therapy.
- Decreasing heat loss.
- Decreasing tourniquet times.
- **Extradural or subarachnoid block.**
 - It is associated with **lower incidence of venous thrombo-embolism** in the early postoperative period due to;
 1. **Vasodilatation** that increases venous blood flow.
 2. **Good postoperative analgesia allowing early ambulation.**
 3. Patients usually receive **more fluids**, decreasing blood viscosity and so, decreasing venous stasis.
 4. Local anesthetics **decreases platelet aggregation.**
 5. General anesthesia decreases blood flow in the lower limbs by 50 %.
 - If the patient receives prophylactic heparin, care should be taken during regional techniques.

III. Postoperative Prophylaxis: Early ambulation.

B. Active Treatment:

I. Treatment of DVT is by anticoagulation therapy.

1. Heparin: 5000 IU i.v. bolus followed by a 24000 - 40000 IU / 24 hrs infusion continued for 5-7 days. Adjust the dose to keep APTT 1.5 -2 times the normal.

N.B.; Low molecular weight heparin.

It can be used in higher doses once daily.

Advantages: it can be given as an outpatient at home.

2. Oral Anticoagulants:

- Warfarin is most commonly used.
- It is started after heparin. After 48 hours, heparin is discontinued and the oral anticoagulant is continued for at least 3-6 months.
- Adjust the dose to keep prothrombin time 1.2 - 1.5 times the normal.
- Take care that:
 - It is not used in pregnancy.
 - Cimetidine, aspirin and 3rd generation cephalosporins potentiate warfarin.

II. Treatment of Pulmonary Embolism: (due to venous thrombosis).

1. Oxygenation:

- From 100 % O₂ up to controlled ventilation and PEEP.

2. Intravascular Volume Expansion.

3. Bronchodilators.

4. Circulatory Support By Inotropes:

- Digoxin, dopamine, or dobutamine.
- Isoproterenol may be used as it decreases the PVR so, some prefer it.

5. Anticoagulation.

a. Heparin:

5000 - 10000 IU i.v. bolus followed by a 24 000 - 40 000 IU 24 hours infusion continue for 5-7 days. Adjust the dose to keep APTT 2-3 times the normal control or the activated clotting time (ACT) 1.5 - 2.5 times the normal.

ANESTHESIA WITH RESPIRATORY DISEASES**b. Oral Anticoagulants:**

- Should be started as early as possible and continued at least for 6 months.

6. Thrombolytics as streptokinase:

- Are used in massive pulmonary embolism not responding to the above measures.
- The risk of hemorrhage with these agents is considerably higher than that with heparin.

7. Pulmonary Embolectomy:

- Open pulmonary embolectomy under cardiopulmonary bypass is considered if C.V.S. effects of the embolism are life threatening.

8. I.V.C. Umbrella filter:

- It is placed percutaneously under local anesthesia with fluoroscopy to prevent recurrent pulmonary embolism.

Q: Discuss hyper-coagulable state?

A: It includes; • Venous hyper-coagulability..... "See above".

• Arterial thrombosis... "See anesthesia with hematological diseases".

II. Venous Air Embolism (VAE)

Etiology:

- It occurs when a vein in which, the pressure is sub-atmospheric, is opened to the atmosphere.
- This is most likely to occur with surgical sites above the level of the right atrium as with head and neck operations in the head-up position e.g. posterior fossa craniotomy in the sitting position.

Pathology:

Effects of VAE depend on:

1. The total volume of air that entered the circulation and the rate of air entry into the circulation:

N.B.; Use of N₂O expands air embolism.

a. Small air bubbles or low entry rate (< 0.5 mL/Kg/min).

Cause insignificant effects and the air bubbles are dissipated by the lungs.

b. Large total volume or high entry rate (> 0.5 mL/Kg/min).

May overcome the ability of the lungs to dissipate air producing clinical signs as;

- Air in the RA or RV causes the **classical Mill wheel murmur** due to turbulence of blood.

- Air in pulmonary vasculature causes pulmonary vascular occlusion by;

1. Mechanical obstruction due to air.
2. Humoral obstruction due to release of PGs causing severe pulmonary VC.

c. Large total volume and rapid entry rate.

This causes acute RV outflow tract obstruction (as it interferes with the pumping of the right heart). This causes acute right sided heart failure resulting in C.V.S. collapse and death.

2. Presence of Patent Foramen Ovale:

- It is present in 10-25 % of the population (asymptomatic).
- Paradoxical air embolism may occur i.e. air enters the systemic circulation and then, may enter the coronary or cerebral arteries.

So, even small air bubbles in i.v. lines and syringes should be avoided in all patients.

Clinical Picture:

It usually occurs intraoperatively.

The same as the C/P of venous pulmonary embolism.

+ **A loud precordial Mill Wheel Murmur**

Monitoring: (intraoperatively)

1- ECG monitor shows arrhythmias.

2- **Capnography:** shows;

- Decreased ETCO_2 and PECO_2 .

- These changes occur early before occurrence of C.V.S. changes.

3- **Pulse Oximetry:** shows;

- Decreased SaO_2 due to decreased gas exchange and decreased CO and tissue perfusion.

4- **Precordial or Esophageal Stethoscope:**

- Detects the Mill Wheel murmur, but the murmur occurs late and is insensitive.

5- **PAP or CVP:**

- Both are increased with significant VAE.

- They are more sensitive than auscultation, but less sensitive than other measures and also occur late.

6- **Invasive ABP Monitoring:**

- Detects hypotension which is variable.

7- **Precordial Doppler Ultrasound Probe:**

- It is placed over the right 4th intercostal space.

- Advantages:

- It is the most sensitive non-invasive investigation, it can detect even a small amount of air in the right atrium.
- It permits continuous monitoring of the heart sounds and murmurs.

8- **Trans-Esophageal Echocardiography (it is the method of choice):**

- It is invasive.

- Advantages: • It is the most sensitive.

- It can detect small air in the right atrium, visualize the cardiac chambers and detect paradoxical air embolism.

Management

It is better to prevent VAE than to treat it.

A. Prevention:

Aim: is to keep small +ve pressure in the veins at the operative site by;

1. **Proper positioning of the patient:** to always maintain small +ve pressure in the veins at the operative site.

2. **Expansion of the intravascular volume.**

3. **Controlled ventilation with PEEP:** It is **controversial** because;

- The clinical values of PEEP are ineffective in increasing the venous pressure significantly.
- PEEP can increase RAP towards or above the LAP. This increases the risk of paradoxical air embolism.

B. Treatment:

When VAE is detected or suspected intraoperatively;

1. **Measures to Prevent Further Air Entry:**

- Notify the surgeon so that he can;
 - Identify the open vein and close it.
 - Flood the surgical field with saline and cover it with wet gauze.

2. **Measures to Increase Venous Pressure at the Operative Site:**

- Especially in head and neck surgery by;
 - Lowering the operative site when possible.
 - Applying manual compression of the jugular veins at the neck at the surgeon's request, bilaterally and intermittently.

ANESTHESIA WITH RESPIRATORY DISEASES**3. Measures to Avoid Expansion of Air Bubbles:**

- Stop N₂O if it was being used.

4. Aspiration of Air Bubbles:

- This is done through either;
 - a. A central venous catheter with its tip located at the junction of the SVC and RA (the most efficacious method), best if the patient is placed in the left lateral position to trap air in the RA.
 - b. A PA catheter which is not effective due to the small caliber of its lumen.

5. Circulatory Support:

- Expansion of the intravascular volume.
- Inotropic support.
- Vasopressor support.
- External cardiac massage.

6. Finally, Right Thoracotomy:

- Is done to aspirate air from the right heart and to perform internal cardiac massage.

N.B.; Intraoperative Pulmonary Embolism.

1. Gas embolism (Air / CO₂ / N₂O).

- a. CO₂ / N₂O embolism usually occur during insufflations procedures as

- Laparoscopy. - Hysteroscopy. - Arthroscopy.

- b. Air embolism can occur with

- Head and neck surgery as ENT (sinus, mastoid) surgeries.
- Orthopedic surgery as arthroscopic, hip and spine surgeries.
- Chest surgery as breast, or open heart surgeries.
- Others as intravascular cannulas (venous / arterial), or epidural injections.

2. Fat embolism: during orthopedic surgery.

3. Venous embolism: surgical manipulation in the pelvis may dislodge a venous thrombus which is already present.

4. Tumor embolism: surgical manipulations of tumors with intravascular extension.

5. Amniotic fluid embolism.

III. Fat Embolism

Causes:

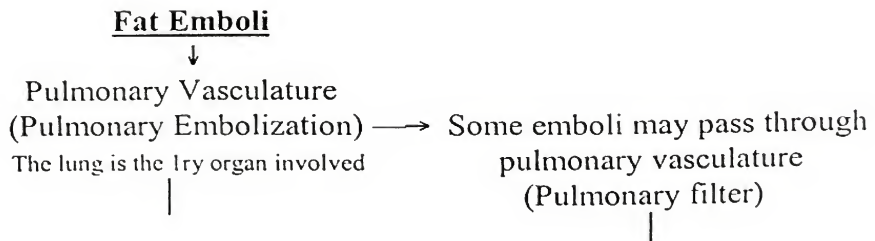
- 1- Long bones or pelvic bone fractures: containing fatty marrow. Fat embolism occurs after 12-48 hours (up to 72 hours).

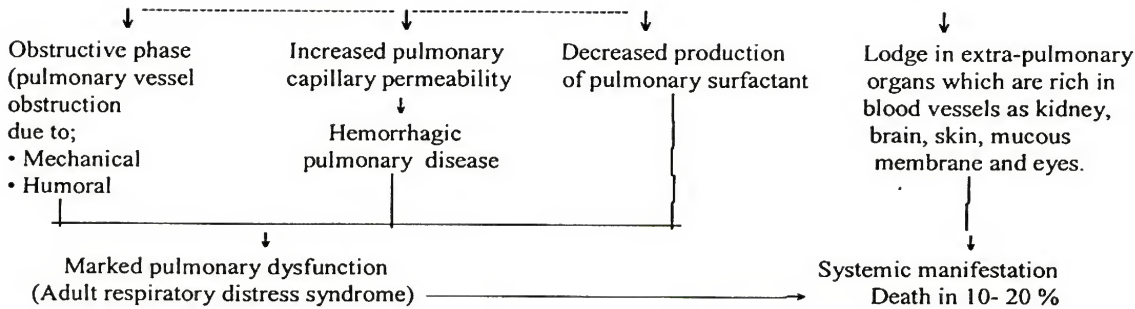
- 2- Orthopedic surgery as;

- Total hip replacement: after insertion of freshly prepared bone cement into the femoral canal, increased pressure within the bone marrow cavity occurs, causing rupture of small venules therefore, fat globules enter the circulation.

- Open reduction and internal fixation of hip fractures.

- 3- Extensive damage to subcutaneous fat deposits e.g. liposuction.

Pathology:

FLASHLIGHTS ON ANESTHESIA

Clinical Picture: usually occurs **within 72 hours** after long bone or pelvic fracture

1. Constitutional Manifestations:

Fever: most of the patients are febrile with a temperature as high as 41- 42 °C.

2. C.V.S. Manifestations:

- Tachycardia.
- Fullness of superficial veins (due to increased venous pressure).
- Hypotension.
- Acute heart failure may occur.

3. Pulmonary Manifestations: (the 1st organ affected).

- Tachypnea.
- Dyspnea.
- Cyanosis.
- Bubbly crepitations.
- Blood-tinged frothy tracheo-bronchial secretions.

4. Systemic Manifestations:

a. Renal impairment: (the 2nd organ affected).

b. **Cerebral** affections: due to damage of cerebral capillaries causing cerebral edema.

- Confusion, disorientation, delirium, acute psychosis, convulsions and coma may occur.
- Local weakness, spasticity, decerebrate rigidity may occur.
- Incontinence (common).

c. **Skin:** (classical finding)

- Petechial hemorrhages in the capillary plexus of the dermis in a distinctive pattern over the shoulders, neck, chest and axillae in 50 % of patients.

d. **Mucous membranes:**

- Petechial hemorrhages in the palate.

e. **Eye:**

- Subconjunctival petechial hemorrhages.
- Emboli may appear within the retinal vessels.
- Streaks of hemorrhage throughout the retina.
- Macular edema.

Investigations:

1- CBC: - Sudden decrease of Hb due to hemorrhage in pulmonary parenchyma.

- Thrombocytopenia due to DIC + (coagulation abnormalities).

2- Chest X-ray:

- Unevenly distributed areas of radio-density
- Increased broncho-vascular markings and congestive hilar shadows.
- Dilatation of the right side of the heart.

3. ECG:

- It shows myocardial ischemia as depressed ST segment and inverted T wave.
- Right ventricular strain.
- Cardiac arrhythmias.

4- Arterial Blood Gases: Arterial hypoxemia.

5. Serum Lipase Level:

- It is non specific. It can occur after any trauma without fat embolism.

ANESTHESIA WITH RESPIRATORY DISEASES

6. Detection of Fat in: urine: (lipuria), blood, or tissues: (e.g. sputum, retina).

Management:**A. Prophylaxis:**

- Gentle handling of the patient.
- Immobilization of long bone fractures.
- Early splinting of long bone fractures.

B. Treatment:

1. Resuscitative measures to correct shock.

2. Pulmonary support:

- O₂ therapy.
- IPPV + PEEP or CPAP.
- Rapid digitalization.
- ETT suction to decrease secretions.

3. Cerebral manifestations:

- Sedation and anticonvulsive therapy.

4. Corticosteroids: doubtful value

- Hydrocortisone 100 mg / 6 hrs i.v.

5. Low dose heparin (not in anticoagulant doses).

2500 IU / 6 hrs i.v. (It clears lipemic plasma and stimulates lipase activity).

6. Low molecular weight dextran:

- I.v. to counteract intravascular thrombosis when there is increased ESR.

IV. Amniotic Fluid Embolism**Pathology:**

Entrance of amniotic fluid into the circulation causes pulmonary vascular occlusion due to;

- Mechanical obstruction.
- Humoral obstruction by PGs release which produce pulmonary VC.

Clinical Picture:

It is usually sudden and unpredictable during labor or immediately post-partum.

C/P of pulmonary embolism occursthe same as venous pulmonary embolism.

- + Convulsions in 10 % of cases.
- + If lry resuscitation is successful, DIC may follow.
- + Mortality rate is 80 %.

Investigations:

The same as venous pulmonary embolismsee above.

+ Diagnosis is confirmed by finding fetal debris in

- The central venous blood of the mother.
- Sputum.
- Lung tissue (at autopsy).

Treatment:

Nonspecific and supportive.

- 1) Oxygenation 100 %.
- 2) Mechanical ventilation may be needed.
- 3) Circulatory support as inotropes and vasopressors.
- 4) Replacement of blood and clotting factors.

Acute Respiratory Failure

Definition:

It is inability of the lung to provide adequate arterial oxygenation
 \pm adequate CO_2 elimination.

It causes PaO_2 to be < 50 mm Hg in presence of O_2 supplementation.

+ PaCO_2 to be > 50 mm Hg in absence of respiratory compensation of metabolic alkalosis.

N.B.; pH of arterial blood can distinguish between acute and chronic respiratory failure as the follows;

- In acute respiratory failure, there may be an abrupt increase in PaCO_2 causing decreased pH.
- In chronic respiratory failure, there is a slow increase in PaCO_2 causing normal pH (between 7.35 – 7.45) due to compensatory renal tubular reabsorption of HCO_3^- .

By using values of PaO_2 and PaCO_2 , to determine the type of respiratory failure. It is a theoretical concept and not useful in clinical practice.

	Type I (Lung Pathology)	Type II (Ventilatory Pump Failure) (Hypoventilation)
There is	- $\downarrow \text{PaO}_2$ + normal or $\downarrow \text{PaCO}_2$	- $\downarrow \text{PaO}_2$ + $\uparrow \text{PaCO}_2$
Causes	1- Obstructive lung disease as severe acute asthma. 2- Restrictive lung disease as - Acute intrinsic (pulmonary edema; cardiogenic or non cardiogenic) - Chronic intrinsic (severe pulmonary fibrosis)	1- Obstructive lung disease as severe acute asthma or severe COPD. 2- Restrictive lung disease as - Chronic extrinsic as neuromuscular disease, or morbid obesity. 3- Hypoventilation as overdose of respiratory depressant drugs.

This classification is not used clinically as many diseases can produce the tow types according to the stage of the pathology.

Treatment

1. O_2 Supplementation:

- Aim: To maintain the PaO_2 between 60-80 mm Hg.

There is no value in maintaining $\text{PaO}_2 > 80$ mm Hg because Hb saturation is nearly 100 % at this level and to avoid O_2 toxicity.

- FiO_2 : - It should not exceed 0.5 (50 % inspired O_2) for > 24 hrs to avoid pulmonary O_2 toxicity.

- If ordinary methods (venturi, face mask, nasal catheter..) can not maintain $\text{PaO}_2 > 60$ mm Hg with FiO_2 at 0.5, administration of CPAP or PEEP is required.

- Patients dependent on the hypoxic drive may show respiratory depression by O_2 so, titrate FiO_2 gradually with monitoring PaCO_2 .

If PaCO_2 increases, assisted ventilation is required.

Method of O_2 Administration: "See pharmacology, O_2 therapy".

2. Mechanical Ventilation:

..... "See later in ICU chapter".

3. Nitric Oxide (NO) Inhalation:

It is used in a dose of 5-80 part per million (ppm). It decreases PAP resulting in increased arterial oxygenation without systemic VD.

4. Removal of Secretions:

- Adequate systemic hydration.
- Humidification of inspired gases.
- Tracheo-bronchial suctioning of secretions.
- Chest physiotherapy.
- Bronchoscopic removal of inspissated secretions.

ANESTHESIA WITH RESPIRATORY DISEASES**5. Control of Infection:**

- Systemic antibiotics are given according to culture and sensitivity tests of pulmonary secretions.
- It is not recommended to give a prophylactic antibiotic without evidence of infection as this may cause overgrowth of resistant bacteria or fungi.

6. Optimization of Intravascular Volume:

- It is monitored by;
 - **PCWP:** should be 15 mm Hg (> 15 mm Hg indicates excessive i.v. volume and < 15 mm Hg indicates inadequate i.v. volume).
 - **UOP:** should be 0.5-1 mL/kg/hr.
 - **Body weight:** It should be reduced by 0.2-0.4 Kg/day.
(If the body weight is stable or increased, it indicates excessive fluid retention).
 - **CVP:** is probably not a reliable guide for i.v. volume.
- If there is excessive accumulated fluid in the lung, use drug induced diuresis e.g. furosemide or dopamine (care is taken for their side effects).

7. Cardiovascular Support:

Inotropic support – vasopressors.

8. Nutritional Support:

- Value:
 1. To improve skeletal muscle power.
 2. To provide phosphate and Mg. Both are essential for normal muscle power.
- As muscle weakness may cause failure of weaning from the ventilator although no longer respiratory failure is present.
- Increasing caloric intake increases metabolism with more CO₂ production. So, it requires increasing alveolar ventilation.

9. Prophylaxis Against Stress Ulcer and DVT:

N.B.; N₂O = Nitrous Oxide.

NO = Nitric Oxide.

NO₂ = Nitrogen Dioxide.

N₂ = Nitrogen.

Nitric Oxide (NO)

It was previously called endothelium-derived relaxing factor (EDRF).

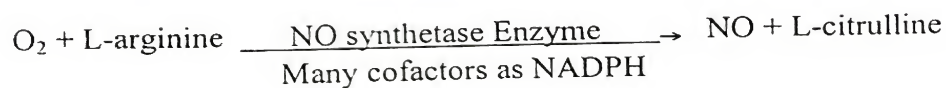
It was discovered in 1987.

Nitric Oxide (NO) Molecule

- It is a small uncharged molecule and highly lipid soluble so, it can cross the cell membrane freely.
- It has an unpaired electron so, it acts as a free radical.

Endogenous NO Synthesis

- It is formed in a 5 electron oxidation reaction in which:



Three types of Nitric oxide synthetase enzymes (NOS) are present;

1. Neuronal NOS (nNOS) (NOS-isoform I).
2. Endothelial NOS (eNOS) (NOS-isoform III).
3. Immunological (iNOS) (NOS-isoform II).

Constitutive NOS	Inducible NOS
It includes : nNOS & eNOS It is present in: - Endothelial cells. - Neurons. - Peri-vascular nerve fibers. - Adrenal medulla. - Macula densa of the kidney.	It includes: iNOS It presents in: - Macrophages. - Hepatocytes - Vascular smooth muscles. It is usually not present under basal conditions.
Activation: By shear forces. It requires an increase in IC Ca^{++} for its activation as IC Ca^{++} binds to calmodulin producing Ca^{++} -calmodulin complex which activates constitutional NOS i.e. Ca^{++} dependant enzyme. It produces small amounts of NO (Picomoles).	Activation: It requires stimuli as endotoxins (lipopolysaccharide) and cytokines. This causes transcription of inducible NOS gene increasing inducible NOS (it does not require IC Ca^{++}). It produces large amounts of NO (nanomoles).

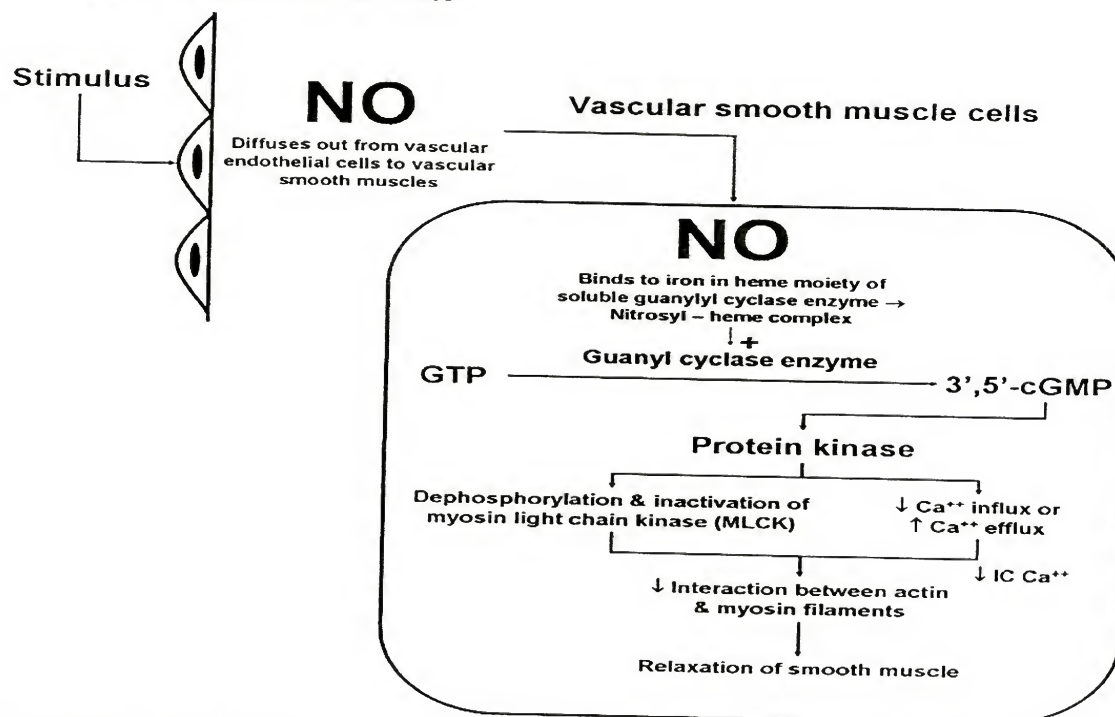
Physiological Effects of Endogenous NO:

1. C.V.S:

- It produces VD of the blood vessels all over the body.
- It regulates SVR and PVR, CO distribution and coronary and cerebral circulations.
E.g. it mediates the effect of CO_2 on CBF as it causes cerebral VD which increases CBF without altering cerebral auto-regulation.
- So;
 - Its decreased production causes vasospasm which in turn causes systemic hypertension, pulmonary hypertension, angina and erectile dysfunction.
 - Its increased production causes excessive VD which in turn causes septic shock, and neuronal toxicity after ischemia.
 - It modulates ischemic / reperfusion injury (e.g. transplantation) of the heart, lung, kidney and liver.

Molecular Mechanism of VD:

Vascular endothelial cells



GTP = Guanosine 5'- tri-phosphate

cGMP = Guanosine 3'-5'- cyclic mono-phosphate

Figure; 8-11 Molecular mechanism of NO

ANESTHESIA WITH RESPIRATORY DISEASES

- NO production is increased by
 - Physiologic stimuli: blood flow, shear stress, hypoxia and hypercarbia.
 - Pharmacologic stimuli: serotonin, and histamine.

N.B.; VD induced by nitro-dilators as GTN, SNP and hydralazine are believed to be due to increased NO production (figure 8-18).

b. Heart: **-ve inotropic** and **-ve chronotropic** effects.

2. Nervous System:

- It may act as a **neurotransmitter** in the brain, spinal cord and peripheral nervous system.
- In the brain;
 - It regulates hormone release in the hypothalamo-pituitary axis.
 - In nNOS knock out (deficient) mice, there is a significant decrease in the infarct size after focal cerebral ischemia compared to wild-type mice. In contrast, in eNOS knock out mice there is a significant increase in the infarct size so, in the future, designing drugs that selectively stimulate e NOS and inhibit nNOS will increase ischemic tolerance of neuronal tissues.

3. Platelets:

- It decreases platelets (and neutrophils) aggregation and adhesion (i.e. synergistic action to prostacyclin).

4. Immunological (Cytotoxic):

- It causes damage to bacteria, fungi, protozoa and tumor cells because cytokines cause activation of macrophages, induction of NOS enzyme occurs increasing NO production with its cytotoxic effect as;
 - DNA trauma or damage.
 - Tissue damage by peroxynitrites, hydroxyl radicals and nitrogen dioxide.
 - Inhibition of mitochondrial enzymes.
- It may play a role in transplant rejection.

5. Inflammatory Modulation:

- It decreases leukocytes adhesion to endothelial cells.
- It alters cytokine release.

NO Half Life:

It is ultra short < 5 sec due to its rapid oxidation to nitrites and nitrates and its antagonism by substances such as Hb.

Inhaled NO**Action:****1. Selective Pulmonary Vasodilator Action:**

It has 2 types of selectivity;

- Dose independent selectivity i.e. selective to pulmonary > systemic vessels.
 - Dose dependent selectivity (lost in high doses) i.e. it is distributed to the well ventilated alveoli > non-ventilated alveoli, then it diffuses to the adjacent pulmonary vascular bed causing relaxation of vascular smooth muscles and producing selective pulmonary VD. This causes;
 - Decreased intrapulmonary shunt with maintaining V/Q matching. This improves arterial hypoxemia.
 - Decreased PVR with decreasing pulmonary hypertension.
2. It has no systemic effects because any amount diffusing to the blood is rapidly inactivated by Hb.

Therapeutic Uses:**1. Acute Respiratory Distress Syndrome (ARDS):**

- In ARDS, there are 2 main pathological features:

1. Arterial hypoxemia.
2. Pulmonary hypertension.

NO causes a selective pulmonary VD action, as above. Therefore, this;

1. Improves arterial hypoxemia:

- It is short-lived only for 1-2 days.
- It has an additive action with other methods e.g. prone position ventilation.

2. Improves pulmonary hypertension:

So improves RV performance and pulmonary edema.

Both lead to enhanced lung healing.

- Inhaled NO should be **continuously** administered.

2. Pulmonary Hypertension:

As 1- 1ry pulmonary hypertension.

2- 2ry pulmonary hypertension.

3- Persistent pulmonary hypertension of the newborn.

3. Chronic Pulmonary Disease:**a. COPD, chronic asthma, pulmonary fibrosis, and respiratory failure:**

As NO produces selective pulmonary VD and bronchodilatation. This improves arterial hypoxemia.

b. Pulmonary edema of high altitudes:

It has elements of pulmonary hypertension and increased alveolo-capillary membrane permeability.

4. Perioperative for Cardiac Surgery:

a. Pulmonary hypertension occurring after mitral valve surgery.

b. Surgery for congenital heart disease and pulmonary hypertension.

c. Pulmonary hypertension occurring after cardio-pulmonary bypass.

- As pulmonary hypertension occurs due to endothelial dysfunction or protamine sulfate reaction.

d. Cardiac transplantation:

It is given preoperatively to determine the presence of reversible pulmonary hypertension in patients scheduled for cardiac transplantation because irreversible pulmonary hypertension contraindicates cardiac transplantation.

It is given postoperatively to treat RVF occurring after cardiac transplantation.

5. Perioperative for Lung Surgery:

- During one lung ventilation.

- During lung transplantation:effects as above.

6. Perioperative for Organ Transplantations:

E.g.: in lung, liver, kidney, heart transplantations, NO decreases ischemic/reperfusion injury "see above".

7. Congenital Diaphragmatic Hernia:

Is characterized by; - Potentially reversible pulmonary hypertension.

- Arterial hypoxemia.

- Systemic hypotension.

So, NO may be used in selected babies to avoid use of ECMO.

8. Sickle Cell Disease:

NO - Decreases sickling.

- Treats acute chest syndrome.

ANESTHESIA WITH RESPIRATORY DISEASES

- Decreases pain associated with vaso-occlusive crisis.

9. Other Effects:

- NO inhibits leukocyte infiltration and inflammation.
- NO inhibits superoxide production and scavenges O₂ free radicals therefore, it decreases O₂ toxicity so, it attenuates vascular damage and smooth muscle proliferation.

Dose:

One to forty parts per million (ppm)

In ARDS, it is used continuously over 1-3 weeks.

Side Effects:**1. Met-hemoglobinemia.****2. Platelet Dysfunction:**

NO decreases platelet aggregation and adhesion so, it prolongs the bleeding time.

3. Formation of Toxic Metabolites as nitrogen dioxide (NO₂): when it reacts with O₂ or air. NO₂ may cause pulmonary edema and alveolar hemorrhage.

4. Rebound Phenomenon:

It occurs on sudden discontinuation of inhaled NO as pulmonary hypertension occurs more than the baseline levels.

5. Mutagenicity.**6. Delaying Lung Repair and Recovery:**

As NO redistributes blood flow away from the damaged hypoxic region.

7. Hemodynamic Instability:

- In patients with pre-existing severe LV dysfunction, NO improves RV function due to pulmonary VD causing a small increase in LV volume which in turn increases LVEDP and pulmonary edema.

Unilateral Decreased Breath Sounds During GA**Causes:**

1. Inadvertent placement or migration of E.T.T. into one bronchus especially the right. E.g. trendelenburg (head down position) may advance the tip of ETT 1-2 cm.
2. Pneumothorax.
3. Atelectasis.
4. Mucous plug.

Precautions:

1. Ascultate the chest for equal breath sounds during;
 - Initial placement of the tube and its fixation.
 - Positioning of patients.
2. Confirm by length marks on tubes.
 - Adult male → 20 – 22 cm at teeth.
 - Adult female → 19 – 21 cm at teeth.
 - Children → Age / 2 + 12.
3. Feel the cuff of the tube in the supra-sternal notch.

CHAPTER 9

ANESTHESIA WITH CARDIOVASCULAR DISEASES

Automaticity:

It is the ability of self excitation and initiation of an impulse.

Excitability:

It is measured by the strength of an electrical impulse required to excite the heart when applied at selected times in the cardiac cycle.

Determinants of Ventricular Performance:

A) Cardiac Output (CO) (Q)

It is the volume of blood pumped by the heart per minute.

$CO = \text{Stroke Volume (SV)} \times \text{Heart Rate (HR)}$

$= 70 \text{ mL} \times 70 \text{ beat/min} = 5 \text{ L/min}$ in a 70 Kg man normally

It represents the ventricular systolic function.

B) Cardiac Index (CI):

$CI = \frac{CO}{\text{Body Surface Area}} = 3 \text{ L/min/m}^2$ in a 70 kg man (range 2.5-4.2 L/min/m²)

Control of CO

I. Heart Rate (HR)

Increased HR is accompanied by an increase in contractility (Bowditch effect or Staircase phenomenon).

II. Stroke Volume (SV)

It is the volume pumped per contraction.

Factors affecting the SV;

- 1) **Preload:** It is the end-diastolic volume and depends on ventricular filling.
- 2) **Afterload:** It is the tension against which the muscle contracts.
- 3) **Contractility (Inotropic state** i.e. ino- = fiber and tropes = to move): It is related to the force of contraction which is affected by the initial fiber length (Frank-Starling mechanism) (Starling's law).
- 4) **Wall Motion Abnormalities:** due to ischemia, infarction, hypertrophy.
- 5) **Valvular Dysfunction:**
 - Stenosis of the A-V (tricuspid or mitral) valve leads to decreased SV primarily by a decrease in ventricular preload.
 - Stenosis of the semi-lunar (pulmonary or aortic) valve leads to decreased SV primarily by an increase in ventricular afterload.
 - Regurgitation of A-V valve leads to a fraction of the SV returning backward into the atrium during systole.
 - Regurgitation of the semi-lunar valve leading to a fraction of the SV returning backward into the ventricle during diastole.

The Cardiac Cycle (Wiggers Cycle)

The cardiac cycle, fully assembled by Lewis, but first conceived by Wiggers, yields important information on the temporal sequence of events in the cardiac cycle (figure 9-1).

Notes: • A cardiac cycle is about 0.80 sec. (systole = 0.30 sec and diastole = 0.40 sec).

- Isometric contraction phase (ICP) i.e. increasing tension without shortening.
- Isometric relaxation phase (IRP) i.e. decreasing tension without lengthening.

- Most diastolic ventricular filling occurs passively before atrial contraction.

Contraction of the atria normally contributes 20-30 % of ventricular filling.

- The notch in the aortic pressure (incisura) is due to transient backflow of blood into the left ventricle just before aortic valve closure.

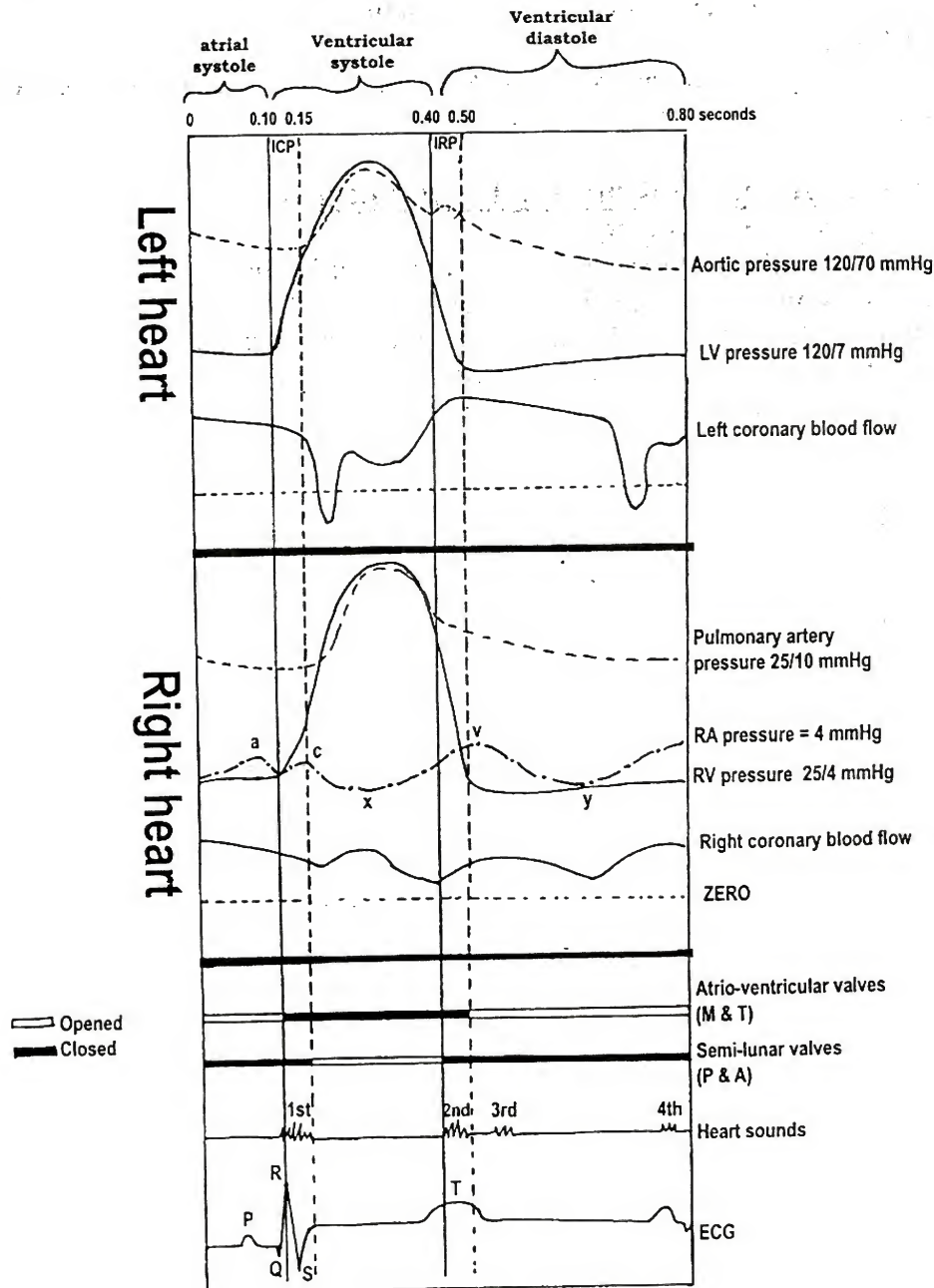


Figure 9-1; Cardiac cycle

Left Ventricular Function

A) Systolic (Inotropic) Function:

- LV systolic function is reflected in the **ability of the LV to empty**. It describes the **contraction phase of myocardial performance**. It is related to the release of Ca^{++} from the sarcoplasmic reticulum and its movement into the cells
- It is determined mainly by LV **contractility** so, both are considered to be interchangeable.

B) Diastolic (Lusitropic) Function:

- It describes the **relaxation phase of myocardial performance**. It is related to the uptake of ionized Ca^{++} into the sarcoplasmic reticulum.

Arterial Blood Pressure

The normal values vary with age and sex. They increase with age

<u>Age (years)</u>		<u>BP mm Hg</u>
10	→	100/65
20	→	110/70
30	→	115/75
40	→	120/80
50	→	125/82
60	→	130/85
70	→	135/88
80	→	140/90

1) Mean Arterial Pressure (MAP) – $\text{CVP} = \text{SVR} \times \text{CO}$

As CVP is normally very small and can be ignored.

So $\text{MAP} = \text{SVR} \times \text{CO}$

2) $\text{MAP} = \text{Diastolic BP} + \frac{\text{Pulse Pressure}}{3}$

Pulse Pressure = Systolic BP – Diastolic BP

Control of ABP

A) Immediate Control (within seconds)

It is the function of the autonomic nervous system and the vasomotor center in the medulla.

Decreased ABP; stimulates sympathetic activity,
increases adrenal secretions, and
decreases vagal activity.

Resulting in systemic VC, increased HR, and contractility. These increase ABP and distribute blood from the skin, gut, skeletal muscles to the heart, brain & kidneys.

The reverse occurs with increased ABP.

N.B.; **Baroreceptor Reflex:**

- Baroreceptors are present in the bifurcation of the common carotid arteries and the aortic arch.
- A decrease in BP decreases baroreceptor discharge which in turn stimulates the vasomotor center. This causes systemic VC and decreases vagal activity. The reverse occurs with increased ABP (baroreceptor reflex).
- All volatile anesthetics depress baroreceptor response (isoflurane and desflurane have the least effect).

B) Intermediate Control (within minutes)

By; 1. Renin-angiotensin-aldosterone system: angiotensin II is a potent arteriolar vasoconstrictor.

2. Arginine vasopressin (AVP): with decreased BP, it is a potent arteriolar vasoconstrictor.

ANESTHESIA WITH CARDIOVASCULAR DISEASES

3. Alteration in capillary fluid exchange due to the effect of BP on capillary pressure as decreased BP shifts fluid from the interstitial to the intravascular space.

While increased BP shifts fluid from the intravascular to the interstitial space.

C) Long Term Control (within hours)

By the kidney as decreased BP leads to Na^+ (and H_2O) retention, while increased BP leads to Na^+ (and H_2O) excretion.

Coronary Circulation**Anatomy:**

a- Right coronary artery (RCA); gives the following branches;

- Vasa vasorum to the ascending aorta and pulmonary trunk.
- A branch to the A.V. node.
- A marginal branch along the inferior border.

b- Left coronary artery (LCA); gives the following branches;

- Vasa vasorum to the ascending aorta and pulmonary trunk.
- A branch to the S.A. node.
- Anterior inter-ventricular artery (left anterior descending artery).
- Circumflex branch (continuation of left coronary artery).

N.B.; SA node is supplied by the RCA in about 50-60 % of humans and by the left circumflex artery in the remaining 40-50 %.

AV node is supplied by the RCA in 85- 90 % of humans and by the left circumflex in the remaining 10-15 %.

Control of Coronary Blood Flow

- In an average adult male at rest, coronary blood flow = 250 mL/min.

It increases up to 5 folds during maximal exercise.

- Coronary perfusion pressure = Arterial diastolic pressure – LV end diastolic pressure

- Auto-regulation controls blood flow between perfusion pressures of 50-120 mm Hg. Beyond this range, blood flow becomes increasingly pressure dependent.

Myocardial O_2 Balance

Coronary venous O_2 saturation is normally 30 % (and $\text{P}\bar{\text{v}}\text{O}_2 = 30$ mm Hg). The myocardium normally extracts 65 % of O_2 in the arterial blood (it is near the maximum), compared to 25 % in most other tissues. So, the myocardium (unlike other tissues) cannot compensate for reductions in blood flow by extracting more O_2 from Hb. So, any increase in myocardial metabolic demand must be met by an increase in coronary blood flow.

Factors Affecting the Myocardial O_2 Supply Demand Balance**A) Decreased O_2 Supply:****1. Decreased coronary blood flow:**

(I.e. decreased coronary perfusion pressure which equals diastolic BP – LVEDP).

- HR: as increased HR leads to decreased diastolic time which in turn decreases supply.
- Coronary perfusion pressure: - Hypotension decreases aortic diastolic pressure which in turn decreases supply.
- Increased preload increases LVEDP which in turn decreases supply.
- Coronary vascular diameter: - Hypocapnia causes coronary VC.
- Coronary spasm or occlusion (atherosclerosis is the commonest cause).

2. Decreased arterial O_2 content and availability:

- Anemia i.e. decreased Hb.
- Hypoxemia i.e. decreased PaO_2 .
- Decreased O_2 release from Hb.

B) Increased O_2 Demand:

1. HR: as increased HR leads to increased demand.
2. Increased basal requirement.

3. Increased wall tension: - Increased preload (LVEDP) which in turn increases demand.
 - Increased afterload which in turn increases demand.
4. Increased contractility.

Derived Hemodynamic Variables

- 1- Cardiac Output (CO) = $SV \times HR$ = 5 Liter/min.
 2- Cardiac Index (CI) = CO/BSA = 3.2 Liter /min/m²
 3- Stroke Volume (SV) = $CO/HR \times 1000$ = 80 mL
 4- Stroke Index (SI)
 5- Systemic Vascular Resistance.
 6- Pulmonary Vascular Resistance.
 7- Left Ventricular Stroke Work Index.
 8- Ejection Fraction (EF) = $\frac{EDV - ESV}{EDV}$ = more than 0.6

9- Diastolic-Pressure Time Index (DPTI)

= Coronary perfusion pressure x diastolic time

It is used as a measure of left ventricular blood flow (**O₂ Supply**)

10- Tension-Time Index (TTI) = systolic BP x systolic time.

It is used as a measure of **O₂ demand**.

11- Endocardial Viability Ratio

It is the ratio of 2 indices $DPTI / TTI$ = more than 1 normally.

It is used as a measure of **O₂ supply-demand balance**.

If it is < 0.7, it indicates subendocardial ischemia.

12- Rate-Pressure Product (RPP)

= systolic arterial pressure x HR = 9600 mm Hg /min.

13- Triple Index (TI)

= systolic arterial pressure x HR x PCWP

N.B.; Both (10), (12) and (13) are used to measure myocardial **O₂ demand**.

Angina threshold for RPP ranges from 15 000-20 000 mm Hg /min.

It is usually recommended to keep RPP below 12 000 and TI below 150 000

High RPP and TI indicate a potential danger of ischemia but, normal or low values do not rule out ischemia. Patients with tachycardia and hypotension may have a normal RPP while both tachycardia and hypotension may produce ischemia.

CVS Pressures

	Range (mmHg)	Mean (mmHg)
Central Venous Pressure (CVP)	0-8	4
RA Pressure	0-8	4
RV- Systolic pressure	14-30	25
- End diastolic pressure	0-8	4
Pulmonary Artery – Systolic	15-30	25
- Diastolic	5-15	10
- Mean (PAP)	10-20	15
PCWP mean	5-15	10
LA Pressure	4-12	7
LV - Systolic pressure	90-140	120
- end diastolic pressure	4-12	7

C.V. complications accounts for 25-50 % of deaths after non-cardiac surgery so, many trials have been done to predict the incidence and percentage of unwanted outcomes.

It is related to the development of postoperative cardiac complications after non-cardiac surgery.

Goldman's Cardiac Risk Index in Non-Cardiac Surgery:

Preoperative Factors:

<u>Preoperative Factors:</u>	<u>Points</u>
1. S ₃ heart sound gallop ----- or increased jugular venous pressure (distension).	11
2. Myocardial infarction in the preceding 6 months -----	10
3. A rhythm other than the sinus rhythm or premature atrial contraction (on preoperative ECG)-----	7
4. More than 5 premature ventricular contractions/min-----	7
5. Age > 70 years old -----	5
6. Emergency Surgery -----	4
7. Intraperitoneal, intrathoracic or aortic operations-----	3
8. Significant aortic stenosis -----	3
9. Poor general physical status as defined by any one of the following: -----	3
<ul style="list-style-type: none"> ● Arterial blood gases <ul style="list-style-type: none"> - PaO₂ < 60 mm Hg - PaCO₂ > 50 mm Hg - HCO₃⁻ < 20 mmol/L - S.K⁺ < 3.0 mmol/L ● Renal function tests <ul style="list-style-type: none"> - BUN > 7.5 mmol/L or > 50 mg/dL - S. creatinine > 270 μmol/L or > 3.0 mg/dL ● Liver function tests <ul style="list-style-type: none"> - SGOT abnormal - Chronic liver disease. 	53 Total

(1) Type and Site of Surgery: (the most important)

Cardiac risk stratification related to non-cardiac procedures

a. High Risk (> 5% chance of death or non-fatal myocardial infarction)

- Emergency surgery especially in the elderly.
- Procedures with massive blood loss or fluid shifts.
- b. Intermediate Risk (1- 5% chance of death or non-fatal myocardial infarction)**
- Carotid artery surgery.
- Elective intra-abdominal or intra-thoracic surgery.
- Prostatic surgery.
- c. Low Risk (< 1% chance of death or non-fatal myocardial infarction)**
- Endoscopic surgery.
- Peripheral surgery.
- Major vascular surgery.
- Peripheral vascular surgery.
- Major head and neck surgery.
- Orthopedic surgery.
- Ocular surgery.
- Breast surgery.

(2) Wide Hemodynamic Variations.

- (3) Duration of Surgery > 3 hrs.
- (4) Type of Anesthesia.
- (5) Experience of Anesthetist, Surgeon or Assistants.
- (6) Monitoring.

C. Postoperative Risk Factors

- (1) Pain relief.
- (2) Availability of high dependency care or an ICU facility.
- (3) Anemia.
- (4) O₂ therapy.

N.B.; High risk periods during anesthesia: - Induction and intubation. - Postoperative period.

General Principles (Aim) of Anesthesia for Patients with C.V.S. Diseases:

1. **Heart:** Adequate oxygenation and adequate balance of myocardial O₂ supply to demand throughout. So, decrease the risk of perioperative ischemia and infarction.
2. **Tissues:** Adequate CO and ABP to allow adequate tissue and organ perfusion especially cerebral, coronary, renal and hepatic.

Hypertension

It is the commonest cause of death and disability in most western societies

Incidence: 1: 5 of all surgical patients.

Definitions:

- Sustained increase of systolic and diastolic blood pressure above the normal range for age, sex and weight regardless of the 1ry cause.

Levels of Hypertension

- (1) Labile (borderline) hypertension: $\frac{140-159 \text{ mm Hg systolic}}{90-99 \text{ mm Hg diastolic}}$

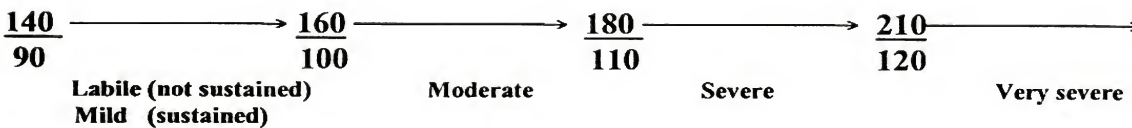
not consistent, usually precedes sustained hypertension.

- (2) Mild hypertension: sustained $\frac{140-159}{90-99}$

- (3) Moderate hypertension: sustained $\frac{160-179}{100-109}$

- (4) Severe hypertension: sustained $\frac{180-209}{110-119}$

- (5) Very Severe hypertension: sustained $\frac{>210}{>120}$



N.B.; - Accelerated hypertension:

It is a recent, sustained and progressive increase in ABP usually with the diastolic pressure > 110 mm Hg with renal dysfunction.

- Malignant Hypertension:

It is a true medical emergency, characterized by very severe hypertension with papilloedema and frequently encephalopathy.

ANESTHESIA WITH CARDIOVASCULAR DISEASES

- **Systolic hypertension only + wide pulse pressure** occurs in

1- Arteriosclerosis (rigidity of aorta).

2- Increased CO (hyperdynamic circulation) as in case of A-V fistula, thyrotoxicosis, fever, patent ductus arteriosus, beriberi of heart, or aortic regurgitation.

Causes:

A. Essential Hypertension (1ry) 90 % (chronic cases may cause hypertensive crisis)

B) 2ry Hypertension: 10%

1. Renal:

* Acute glomeruli-nephritis.

* Congenital polycystic kidney.

* Chronic pyelonephritis.

* Chronic renal failure.

* Chronic glomeruli-nephritis.

* Renal artery stenosis (H. Crisis).

2. Endocrinal:

* Cushing's disease and syndrome.

* Pheochromocytoma (→ H Crisis).

* Thyrotoxicosis (→ H Crisis with thyro-toxic crisis).

* Conn's disease.

* Acromegaly.

* Myxedema.

3. C.V.S:

* Coarctation of aorta.

* Polyarteritis nodosa.

4. CNS:

* Increased ICP (→ H. crisis).

* Polyneuritis.

* Spinal cord section (→ H. Crisis).

* Guillain Barré syndrome (→ H. Crisis).

5. Drugs:

* Oral contraceptive pills.

* Cocaine, LSD, amphetamine, tricyclic antidepressant (→ H. Crisis).

* Corticosteroids.

6. Others:

* Pregnancy induced hypertension (→ H. Crisis).

* Hypercalcemia.

* Acute intermittent porphyria.

Treatment:

.....See Pharmacology C.V.S.

N.B.; Hypertensive Crisis (Emergency Hypertension):

Definition: Sudden increase of the diastolic BP > 130 mm Hg \pm encephalopathy, congestive heart failure or renal dysfunction (oliguria and proteinuria).

Causes:See above + sudden withdrawal of antihypertensive as β blockers, and clonidine.

Treatment: Aim: Is to decrease diastolic BP to 100-110 mm Hg over a period of several minutes to several hours.

By: Na nitroprusside 0.5-10 μ g/ Kg/min infusion.

+ invasive BP monitoring + UOP.

Anesthetic Management:

Preoperative Management (& Assessment): by (history-examination-investigations).

1. Decision Whether to Delay or to Proceed with Surgery:

- It should be individualized based on:

1- The severity of the preoperative BP elevation.

2- Presence of complications.

3- The type of surgery, if major changes in the preload or the afterload is expected.

- Patients with moderate hypertension (i.e. diastole < 110 mm Hg) and not having any complications, can undergo elective surgery. Actually, other anesthesiologists cancel cases if diastolic BP is > 95 -100 and systolic BP > 160 mm Hg.

- The approach that the patient should be normotensive before elective surgery is not always feasible or necessarily desirable due to altered cerebral and renal autoregulation.
- Patients with **diastolic BP > 110 mm Hg or isolated systolic hypertension > 200 mm Hg**, should be **delayed (postponed)** until BP is controlled over the course of several days as:
 - Acute control within several hours is not advised because it gives no time for resetting of cerebral or renal autoregulation (N.B.; Sublingual Nifedipine (Epilat) is associated with reported cases of severe hypotension and death so, never use it).
 - The uncontrolled hypertensive patients are more liable to severe BP fluctuations during anesthesia which increase the incidence of myocardial ischemia.

2. Severity and Duration of Hypertension "as above".

3. Cause and Type of Hypertension "as above".

N.B.; Failure of diagnosis of pheochromocytoma preoperatively is proved fatal.

4. Complications of Hypertension: (write C/P and investigations of each)

They usually start to occur after 5-10 years and end up with end organ damage after 20 years.

1. Heart: Cardiomegaly, LVF, ischemia and infarction.
2. Vessels: peripheral occlusive disease, and aortic dissection.
3. CNS: cerebrovascular accident (hemorrhagic, thrombotic) transient ischemic attacks, and hypertensive encephalopathy.
4. Renal: impairment.
5. Eye: hypertensive retinopathy, retinal changes parallel severity in other organs (by ophthalmoscopy).
6. Orthostatic changes: i.e. ABP should be measured in both the supine and standing positions as orthostatic changes can occur due to:
Volume depletion (common), excessive vasodilators, or sympatholytic drug therapy. So, preoperative fluid administration can prevent severe hypotension after induction of anesthesia in these patients.

5. Preoperative Drugs Taken:

- Detect **side effects** of antihypertensive drugs taken.....(discuss them).

E.g. Hypokalemia (common finding) by diuretics.

Hypovolemia (common finding) by diuretics so, preoperative fluid is administered

- **Interaction** with anesthetic drugs:

- a- Ca^{++} channel blockers with high doses of opioids cause severe bradycardia.
- b- Reserpine and guanethidine cause marked depletion of norepinephrine from sympathetic nerve endings. This results in exaggerated effects to inhalational anesthetic agents.

- Antihypertensive drugs should be **continued up** to the time of surgery with a small sip of water.

• Acute withdrawal of β blockers or centrally acting antihypertensive drugs e.g. clonidine may precipitate severe hypertension and ischemic attacks.

6. Premedications:

1. **Sedatives:** Decrease preoperative anxiety e.g. midazolam.
2. **Clonidine** 0.2- 0.3 mg: It acts as a sedative, decreases the anesthetic need, and increases hemodynamic stability.
3. **Glycopyrrolate** is preferred (than atropine) as it produces less tachycardia.
4. **Prophylactic transdermal nitroglycerine:** Theoretically, it decreases the incidence of ischemia, but clinically this has not been proved.

Intraoperative Management

Aim:

To maintain ABP stable within 10-20 % of preoperative level because marked variability leads to; - Increased incidence of ischemia of myocardium.

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- Increased incidence of ischemia of cerebral and renal tissues due to altered auto-regulation which is reset to a higher level.

If markedly increased ABP is present e.g. > 180/120 preoperatively, keep ABP in the high normal range $\frac{140-150}{80-90}$ mm Hg.

Monitoring:

Is instituted before induction and maintained throughout the immediate postoperative period.

1. ABP:

- Non-invasive: usually used.
- Invasive: used in;
 - Patients with wide swings of ABP.
 - Major surgery with rapid or marked fluid shifts.
 - Patients on nitroprusside or nitroglycerine.

2. ECG: (see ECG monitoring during anesthesia)

- CM₅ lead II (it detects 80 % of ischemia) or CB₅ configuration.
- Lead II.....for inferior wall ischemia.
- V5.....for anterior and lateral wall ischemia.
- Esophageal lead.....for posterior wall ischemia.
- Automated ST segment analysis monitors and trends.

3. Pulse Oximetry: To detect peripheral blood flow and oxygenation.**4. End-Tidal CO₂:** To maintain normocapnia.**+ 5. CVP.****6. Pulmonary Artery Catheter.**

Indicated in;

- Patients with ventricular dysfunction or failure.
- History of recent myocardial infarction.
- Major vascular or cardiac surgery.

To measure;

- PCWP: to maintain it between 12-18 mm Hg.

It reflects LVED volume and pressure. Both increase in myocardial ischemia.

- CO.
- Sampling of pulmonary arterial blood for mixed venous blood saturation (S \bar{v} O₂).

7. Two-Dimensional Trans-Esophageal Echocardiography (more sensitive than ECG).

Indicated in - Patients suspected to have myocardial ischemia.

To detect - New regional wall motion abnormalities (occur before ECG changes).

- Reduction of systolic wall thickening.
- Ventricular dilatation.

Choice of Anesthesia:**A. Regional Anesthesia:**

It is accepted because it avoids the stress response of intubation.

It is used with care to;

- Avoid hypotension as it causes myocardial ischemia, by prior volume loading, ephedrine, or phenylephrine.
- Avoid patchy or incomplete anesthesia as it increases the patient's stress and increases BP and ischemia.
- Avoid adrenaline containing local anesthetics as they increase ABP and ischemia.

N.B.; Sympathetic block is beneficial in;

- Compensated congestive heart failure as it decreases the afterload.
- Peripheral vascular disease as it causes VD.

B. General Anesthesia:**Induction:**

- Hypertensive patients display accentuated hypotensive response to induction of anesthesia followed by accentuated hypertensive response to intubation.

- Methods to decrease the pressor response to laryngoscopy and intubation....."See before".

Intubation via LMA fastrach is associated with less pressor response than intubation with direct laryngoscopy.

- Induction agent: after preoxygenation.

• Large doses of opioids + appropriate muscle relaxant.

• Etomidate (has the least C.V. effect)

Both are the best.

• Thiopentone, and propofol can be used, but only a sleeping dose as both causes C.V.S. depression.

• Ketamine is contraindicated.

Maintenance:**- According to the Cardiovascular Function of the Patient:**

• In patients with good ventricular function (EF > 50 %), volatile based anesthesia is used.

This is usually done in hypertensive patients only, without any further cardiac complication.

• In patients with bad ventricular function (EF < 50 %), opioid based anesthesia is used.

- Volatile Agents:

A small concentration helps to decrease ABP and allows control of intraoperative rise of ABP.

• **Isoflurane: it is the best agent used** (although there is possibility of coronary steal phenomenon; controversy).

• **Desflurane: It increases the HR resulting in increased O₂ demand. So; it is not preferred.**

• **Sevoflurane: It is used safely.**

- **Opioids:** are of choice as they do not affect ABP (if used alone).

Alfentanil and sufentanil are more effective than fentanyl in preventing intraoperative rise of ABP and HR.

- N₂O:

• N₂O alone (even < 40 %) produces small, but significant myocardial depression.

• N₂O + Opioids produce marked myocardial depression resulting in decreased CO and ABP.

• N₂O + Patients with pulmonary hypertension, pulmonary VC is produced resulting in increased pulmonary vascular resistance.

Generally; N₂O is used safely in patients with hypertension, but N₂O with opioids is better avoided in patients with ischemic heart disease.

- Muscle Relaxant:

• Atracurium, vecuronium and pipecuronium are of choice.

• Pancuronium slightly increases HR and ABP, but if it is used in a small dose and injected slowly, it can be safe.

• D-tubocurarine or alcuronium causes histamine release which causes a severe transient fall in ABP.

- Reversal of Muscle Relaxants:

Use glycopyrrolate (instead of atropine) to decrease the effect on HR.

Intraoperative Complications:**1. Intraoperative Hypertension:**

• 1st, exclude hypoxia or hypercapnia.

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- 2nd, increase the depth of volatile agents, if failed, use one of the following;
 - Nitroprusside, or nitroglycerine: They need invasive BP. They are the most effective.
 - Hydralazine, and trimethaphan.
 - Propranolol, esmolol, and labetalol are contraindicated in asthmatic patient.
 - Nifedipine.

2. Intraoperative Hypotension:

- 1st, decrease the depth of volatile agents. If failed, use one of the following;
 - Increased i.v. fluid rate.
 - Ephedrine i.v.
 - Phenylephrine.

Give the smallest dose and in increments because there is an excessive response to vasopressors in hypertensive patients.

3. Intraoperative Dysrhythmias:

The commonest is nodal dysrhythmias (especially with hypokalemia) so,

- 1st, decrease the depth of volatile agents (halothane).
- Avoid hypocapnia.
- Then according to the heart rate, use either i.v. atropine or β blockers.

4. Intraoperative Ischemia:

- 1st, increase O₂ supply by correcting hypotension, hypoxemia, and anemia.
- and decrease O₂ demand by correcting hypertension, and tachycardia.
- 2nd, nitroglycerine drip, sublingual nifedipine, or i.v. nicardipine.

5. Intraoperative Blood Loss:

These patients are more vulnerable to small changes in the blood volume due to:

- The decreased LV compliance and rigid atherosclerotic vascular tree.
- β blockers used in treatment of hypertension, can prevent the physiologic HR response to blood loss.
- Vasodilators used in treatment of hypertension, can prevent the physiologic VC response to blood loss.

So, careful monitoring with CVP and prompt replacement are essential.

N.B.; Elective Hypotension Anesthesia

- In untreated or uncontrolled severe hypertension, elective hypotension is contraindicated.
- In treated hypertension, elective hypotension is used cautiously, as ABP can be decreased as follows:

Decrease the mean ABP up to 25 %. This coincides with the lower limits of cerebral auto-regulation.

N.B.; Decreased mean ABP up to 55 % coincides with symptomatic cerebral hypoperfusion.

Because, in chronic hypertension, cerebral auto-regulation is reset to a higher level and may and may not return to the normal range after treatment.

Recovery and Extubation:

Must be smooth so, decrease the stress response of extubation by giving 2 min before the extubation one of the following;

- Lidocaine 1.5 mg/kg iv
- Deltiazem 0.1 mg/Kg iv.
- Verapamil 0.1 mg/Kg i.v.

Postoperative Management:

Close monitoring of patients to avoid postoperative hypertension because it increases the risk of ischemia, congestive heart failure or wound hematoma.

Cause:

- Pain (the most common).

- Volume overload.
- Bladder distension.
- Hypothermia (it produces VC).
- Respiratory distress (hypoxia or hypercarbia).

Treatment:

- Treatment of the cause e.g. analgesics for pain, urinary catheter...
- Antihypertensive agents if hypertension persists.

On resuming oral intake, restart oral antihypertensive therapy.

Ischemic Heart Disease

Definition:

Myocardial O₂ demand exceeding its O₂ supply.

Causes: Factors affecting O₂ balance....."see before".

Risk Factors for Disease Development

- | | | |
|-----------------------|--|-----------------------------|
| * Hypertension. | * DM. | * Cigarette smoking. |
| * Hyperlipidemia. | * Advanced age. | * Male patient. |
| * +ve family history. | * Obesity. | * Menopause female patient. |
| * Sedentary life. | * High estrogen containing oral contraceptive pills. | |

Metabolic and Physiologic Consequences of Ischemia:

Effects of acute myocardial ischemia:

- 1- **Increased s. lactate** which is used as a metabolic marker of ischemia.
- 2- The effect on ventricular compliance is related to the cause of the ischemic event. Increased O₂ demand causes **immediate loss of compliance** (i.e. the ventricle becomes stiffer).

So; LVEDP is increased to maintain a given stroke volume.

Then • **Wall motion abnormalities occur as follows;**

- 80 % decrease in coronary blood flow leads to akinesis.
- 95 % decrease in coronary blood flow leads to dyskinesis.
- **Dysrhythmias and ECG changes.**
- **Conduction block.**

On severe increase in the LVEDP, **pulmonary edema** occurs.

Perioperative Cardiac Prediction: "See before".

C/P of Ischemic Heart Disease:

1. Ischemia either chronic stable angina or unstable angina.
2. Infarction.
3. Dysrhythmias (including sudden death) by VF.
4. Ventricular dysfunction (congestive heart failure) causing ischemic cardiomyopathy.

Anesthetic Management:

Preoperative Management (& Assessment):

1. Decision whether to Delay or to Proceed with Surgery (i.e. Detect the Last Attack):

The incidence of perioperative heart infarction is;

- All surgical patients.....0.2 %
- History of coronary artery bypass surgery.....1.2 %
- Previous MI > 6 months.....6 %

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- Recent MI 3-6 months.....15 %
- MI < 3 months.....30-40 %

a- Traditionally; elective surgery should be **postponed** until at least **6 months** after the **last infarction** unless it is an emergency. With improvement of thrombolytics, angioplasty after acute MI, this time interval has decreased.

The American heart Association / American College of Cardiology Task Force: recently, they use **MI < 6 weeks** as the group at highest risk, while after that period the risk is based upon the presentation of the disease and exercise tolerance.

b- Preoperative Detection of Unstable CVS Disease:

Patients with **acute disease as unstable angina**, or decompensated congestive heart failure of an ischemic origin are at a great risk. Therefore, elective surgery should be **postponed** until this unstable disease is resolved e.g. by drugs or trans-cutaneous angioplasty. Only emergency surgery is done.

c- Preoperative Detection of Patient's Need for Further Diagnostic Evaluation:

Patients with dyspnea or angina on mild exertion (**class III and IV**) need further investigations to decide further management. These patients should be **postponed**. Most patients with stable angina or angina on extreme exertion do not need further investigations as it does not change the anesthetic management.

2. Detection of the Severity of Angina:

By history of exercise tolerance.

It is one of the most important determinants of perioperative risks and the need for invasive monitoring.

N.B.; The Canadian Cardiovascular Society Classification of Angina Pectoris:

It describes the amount of effort needed to produce angina pectoris.

Class I: Ordinary physical activity e.g. walking or climbing stairs.

Angina occurs with strenuous, rapid or prolonged exertion.

Class II: Slight limitation of ordinary activity.

Angina occurs with walking, climbing stairs rapidly, walking uphill, after heavy meals, in the cold, or wind, or under emotional stress for few hours.

Class III: Marked limitation of ordinary activity.

Class IV: Inability to do any physical activity as angina occurs at rest.

3. Correction of Possible Risk Factors.

4. Complications of Ischemia: (Detection and management)

* Dysrhythmias.

* CHF.

5. Preoperative Drugs Taken: Anti-anginal treatment especially β blockers should be taken till the time of surgery.

6. Preoperative Investigation:

1. ECG shows;

- Pathologic Q wave (> 1 mm wide) indicates old infarctions.

- Anterior wall: L_1 and $aVL + V_1$ and $V_2 \rightarrow$ Anteroseptal (occlusion of left anterior descending artery)
or $+ V_3 \& V_4 \rightarrow$ Strictly anterior (occlusion of left anterior descending artery)
or $+ V_5 \& V_6 \rightarrow$ Anterolateral (occlusion of left anterior descending artery or left circumflex artery).

- Inferior wall: $\rightarrow L_{II}, III$ and aVF (occlusion of right coronary artery).

- Poor R wave progression.

- The ST segment shows one of the following;

- A transient depression indicates subendocardial ischemia (classic angina).
- A persistent depression indicates subendocardial infarction.
- A transient elevation indicates transmural ischemia (variant angina).

- Non-specific changes.
- T wave changes.
- Long QT interval.
- Dysrhythmias or heart block.
- 2. Chest X ray: to exclude cardiomegaly and pulmonary vascular congestion.
- 3. Holter (Continuous Ambulatory) ECG monitor: to evaluate;
 1. The severity and frequency of ischemic episodes.
 2. Silent ischemia.
 3. Dysrhythmias and anti-arrhythmic drugs.

4. Exercise ECG:

It has a sensitivity of 65-80 % and specificity of 90 %.

5. Cardiac Enzymes:

	<u>Onset</u>	<u>Peak</u>	<u>Duration</u>
S. creatine kinase (MB isoenzyme)	3 hrs	12 hrs	36 hrs
Lactate dehydrogenase (type I)	2 days	6 days	12 days.
Cardiac troponin I			7-10 days
and troponin T			10-14 days

Both troponin I and T are more sensitive. They are normally 0.2 – 0.6 ng/mL

The cardiac enzymes are released due to tissue necrosis.

N.B.: In unstable angina, CK-MB is not elevated, but troponin I and T may be elevated indicating the presence of micro-infarction.

6- Thallium Imaging (Scintigraphy):

- Presence of a cold spot (i.e. does not take thallium) during stress only indicates ischemia, but a constant cold spot indicates infarction.
- Stress can be induced by either;
 - Exercise.

Or • Pharmacologically:

Which is indicated in:

- Intolerance to exercise e.g. peripheral vascular disease.
- Aortic aneurysm as exercise may cause its rupture.

By: a- Drugs producing coronary VD as;

Adenosine: is a direct coronary VD.

Dipyridamole: inhibits adenosine reuptake so, it increases its level leading to coronary VD. It may cause steal phenomenon.

b- Drugs increasing myocardial O₂ demand.

As dobutamine and isoprenalol.

7- Radionuclide Angiography:

- It has a 90 % specificity and sensitivity.
- It detects new abnormal wall motion and the ejection fraction.

8- Two Dimensional Echocardiography:

- It detects abnormal wall motion abnormalities and evaluates cardiac function.
- Stress echocardiography can be done after dobutamine injection.

9- Coronary Angiography and Cardiac Catheterization:

- It is the gold standard for evaluation of coronary artery disease.
- It detects sites of obstruction and evaluates ventricular and valve functions.
- It is done to assess the patient's benefit before;
 - Percutaneous transluminal coronary angioplasty.

Or • Coronary artery bypass grafting.

N.B.: Indicators of significant ventricular dysfunction (bad ventricular function):

- LV Ejection Fraction < 50 % (0.5). It is the most important.

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- LV end diastolic pressure > 18 mm Hg.
- Cardiac index < 2 - 2.2 L/min/m²
- Marked or multiple wall motion abnormalities.

7. Premedications:

The same as hypertension management.....

Intraoperative Management

Aim: To maintain a favorable myocardial O₂ supply-demand balance.

Monitoring..... The same as hypertension.

Choice of Anesthesia..... The same as hypertension.

Recovery And Extubation..... The same as hypertension.

Q: What is the monitoring of myocardial ischemia in the perioperative period?

A: Discuss; • Definition and patho-physiology of myocardial ischemia.

• Preoperative, intraoperative and postoperative management.

Q: What is the postoperative management of MI ?

A: Discuss; • Definition and patho-physiology of myocardial ischemia.

• Preoperative, intraoperative and postoperative management.

Postoperative Management:

Close monitoring of patients to avoid postoperative myocardial ischemia.

It occurs most commonly in the 1st 3 days postoperatively due to;

- Decreased O₂ supplementation.
- The patient starts to move.
- Decreased analgesia given to patients.
- The hyper-coagulable response of surgery (although not proved clinically) due to increased platelet function and number, decreased fibrinolysis, decreased natural anticoagulants (protein C and anti-thrombin III) and increased procoagulants as fibrinogen, factor VIII and VW factor.
- Unintentional hypothermia.
- Presence of anemia.

So, prophylactic measures include;

1. ECG and other investigations (mention them.....) repeated every 8-12 hours the night of the surgery and then every day for 3 days.
2. O₂ supplementation.
3. Proper treatment of postoperative pain.
 - E.g. • NSAIDs (analgesic + anti-platelet).
 - Epidural analgesia (it decreases pain, preload and afterload, and coagulation)
 - Thoracic epidural causes coronary VD.
 - α₂ agonists as clonidine.
 - High dose sufentanil 1 µg/kg/hr + overnight controlled ventilation.
4. Proper treatment of postoperative hypothermia and shivering by warming the patient and pethidine 20-30 mg i.v. with proper oxygenation.
5. Proper detection and treatment of postoperative pulmonary congestion by chest X- ray.
6. Proper treatment of anemia.

If ischemia is detected, manage it "as above".

Valvular Heart Diseases

Preoperative Management (& Assessment) (History-examination- investigation)

1. Assess Severity of the Valve Lesion:

By - History: The most important is exercise intolerance... "see later NYHA classification".

- Examination and investigations "see later".

2. Associated Diseases:

Hypertension, myocardial ischemia and CHF.

3. Associated Complications:

- Pulmonary function by arterial blood gases.

- Liver function by liver function tests.

- Renal function by renal function tests.

4. Preoperative Drugs Taken:

- Usual medications: - Their side effects e.g. digitalis, diuretics.
- They must be taken on the morning of the surgery.

- Anticoagulant therapy: usually given to decrease the risk of thrombosis.

a. For most patients:

- Anticoagulant therapy (e.g. warfarin) can be stopped 2-3 days before surgery and restarted after surgery.

b. For high risk patients:

- Stop warfarin 1 day before surgery and do PT daily (it should not be > 1.5 times the control at the time of surgery). If it is prolonged, give vitamin K or FFP (in emergency surgery).

- After minor surgery: Warfarin can be restarted on the 1st day postoperatively with PT control.

- After major surgery: heparin infusion can be started 12-24 hours postoperatively with thrombin control, until warfarin therapy is restarted once surgical hemostasis is felt to be adequate. This allows rapid reversal of heparin by protamine, besides heparin is short acting.

N.B.; High Risk Patients include;

1. Previous history of embolism.
2. AF.
3. Prosthetic mechanical valves especially in the mitral and tricuspid positions.

- Antibiotic Prophylaxis Against Infective Endocarditis.

Antibiotic recommendations by the American Heart Association include;

I. For Dental, Oral, Nasal, Pharyngeal, Upper Airway Procedures or any Incision and Drainage.

A. Standard:

Adult: Amoxicillin 3g orally 1 hr before and 1.5 g 6 hrs after the procedure.

B. Penicillin Allergy:

Adult: Erythromycin 1 g orally, 2 hrs before and 500 mg 6 hrs after the procedure.
Or clindamycin 300 mg orally, 2 hrs before and 150 mg 6 hrs after the procedure.

ANESTHESIA WITH CARDIOVASCULAR DISEASES**C. High Risk (Prosthetic Valve or Prior Endocarditis):**

Adult: Ampicillin 2 g i.v. or i.m. + gentamicin 1.5 mg/kg (up to 80 mg) i.v. or i.m. 30 min before + Amoxicillin 1.5 gm orally 6 hrs after, or repeat i.v. regimen 8 hrs later.

D. High Risk With Penicillin Allergy.

Adult: Vancomycin 1 g i.v. 1 hr before (infuse over 1 hr).

II. For Genitourinary & GIT procedures.

A. **Standard:** The same as the high risk of group I.

B. **Penicillin Allergy:** The same as the high risk with penicillin allergy of group I.

C. **Low Risk:** The same as the standard of group I.

5. Preoperative Premedications:

Decrease the dose of premedications in proportion to the severity of the ventricular impairment. So, • In good ventricular function, decrease anxiety.

• In poor ventricular function as CHF, omit premedications.

6. Preoperative Investigations:**A. ECG:**

To determine cardiac chamber enlargement, arrhythmias, ischemia...

LAH → Wide P (broad and bifid), best in lead II.

RAH → Tall peaked (P Pulmonale) P wave, best in Lead II.

LVH → Deep S in V₁, tall R in V_{5, 6}, aVL, aVF and left axis deviation.

RVH → Deep S in V_{5,6}, tall R in V₁ and right axis deviation.

B. Chest X-ray:

To determine cardiac enlargement, pulmonary congestion.

C. Investigation for Complications: As;

- Cardiac ischemia.....as before.
- Pulmonary function.....by arterial blood gases.
- Liver function.....by liver function test.
- Renal function.....by renal function test.

D. Investigations to evaluate the severity of the valve lesion:**1. Cardiography:**

An angiographic dye that regurgitates back into the cardiac chamber distal to the diseased valve can assess the severity of valvular regurgitation.

2. Doppler Echocardiography:

Values in valvular heart lesions that it can;

- 1- Determine cardiac murmurs.
- 2- Identify hemodynamic abnormalities associated with physical findings.
- 3- Identify trans-valvular pressure gradient (also by cardiac catheterization) especially in stenotic lesions (MS and AS). Both are considered to be present when the trans-valvular pressure gradient is greater than 10 and 50 mm Hg respectively in absence of CHF. But if CHF is present, only 20 mm Hg can indicate severe AS.
- 4- Determine the valve orifice area.
- 5- Diagnose cardiac valve regurgitation by color flow doppler.

6. Evaluate prosthetic valve function.

3. Cardiac Catheterization:

It measures the pressure gradient across the valves in AS, AI, MI and MS, but in MS, catheterization needs direct measurement of the diastolic gradient between the LA and LV. This requires a trans-atrial puncture, so it is replaced by echocardiography

N.B.: Normally, MV area = $4.0 - 6.0 \text{ cm}^2$ and the mean pressure gradient = $< 2 \text{ mm Hg}$.
AV area = $2.5 - 3.5 \text{ cm}^2$ and the peak pressure gradient = $< 10 \text{ mm Hg}$.

N.B.: Assessment of Patients with Prosthetic heart valves:

Beside the previous assessment;

- 1) Change in the cardiac valve sound or appearance of a new heart murmur.
- 2) Anticoagulant and antibiotic prophylaxis.
- 3) Echocardiography and cardiac catheterization.
- 4) Detection of occult hemolysis caused by prosthetic valve dysfunction by s. bilirubin, reticulocytic count and an increased incidence of cholecystitis may occur.

ANESTHESIA WITH CARDIOVASCULAR DISEASES

	Mitral Stenosis (MS)	Aortic Stenosis (AS)
Causes	1. Rheumatic fever (the commonest). 2. Congenital. 3. Systemic Lupus Erythematosus. 4. Carcinoid tumors.	1. Rheumatic fever. 2. Congenital. 3. Degenerative senile calcification.
Pathophysiology -LAP = left atrial pressure -P++ = pulmonary hypertension -RVF = Right ventricular failure -RVD = Right ventricular dilatation. -LVF = Left ventricular failure -LVD = Left ventricular dilatation -PCWP = Pulmonary capillary wedge pressure -TR = Tricuspid regurgitation -PR = Pulmonary regurgitation -AF = Atrial fibrillation -CHF = Congestive heart failure -LVEDV = Left ventricular end diastolic volume -LVEDP = Left ventricular end diastolic pressure ↑ = Increase or increased ↓ = Decrease or decreased → = Causes or leads to	• MS:→ a- ↑LAP (& ↑PAP and ↑PCWP > 25 mm Hg) → • Acute → pulmonary edema • Chronic → ↑lymphatic drainage from the lung and thickening of the capillary basement membrane i.e. (Irreversible pulmonary VS resistance) → P++ without development of pulmonary edema these → RVD → RVF → TR & PR b- ↓ ventricular filling (especially with AF) → low fixed CO i.e. without a reserve to compensate for changes in HR or ABP. • Mid-diastolic rumbling murmur with pre-systolic accentuation best at mitral area. Opening snap in early diastole, caused by a vibration set in motion when the mobile but stenosed valve initially opens. It disappears if calcification occurs in the valve. • Embolic manifestations especially with AF • Amount of blood flow via MS depends on 1. CO: is low and fixed, HR dependent 2. HR: (diastolic time) as ↑ HR → ↓ diastolic filling time → ↓ CO ↓ HR with limited SV due to the stenosed valve → ↓ CO 3. Atrial systole as AF → loss of atrial contractions → ↓ ventricular filling → ↓ CO 4. Mitral valve orifice (normally 4-6 cm ²) < 1 cm ² → Dyspnea with minimal exertion and at rest (critical MS). 1-1.5 cm ² → Dyspnea with mild to moderate exertion 1.5 - 2cm ² → Asymptomatic	• AS: → a- ↑LVP → LVD → LVF b- ↓ Ventricular ejection → low fixed CO → exertional dyspnea, syncope, angina and sudden death in 15-20% • Harsh ejection systolic murmur on the 2 nd right intercostal space propagated to the carotid and apex. + Slow rising low volume pulse with ↓ pulse + ↓ intensity of S ₂ • Amount of blood flow via AS depends on 1. CO: low and fixed, HR dependent 2. HR: (systolic time) as ↑ HR → loss of timed atrial stroke → ↓ CO and ↓ time of coronary filling → angina ↓ HR → with limited SV → ↓ CO. 3. AV orifice (normally 2.5-3.5 cm ²) 0.5-0.7 cm ² → critical AS 0.7-0.9 cm ² → mild to moderate symptoms 0.9-2 cm ² → asymptomatic
Treatment	1. Medical: ↓ physical activity, ↓ salt intake, diuretics, digoxin, β blockers, and anticoagulants. 2. Surgical: • Percutaneous trans-septal balloon valvoplasty especially in severely ill pregnant patients • Open valvo-plasty • Valve replacementAs MS

Mitral Regurgitation (MR)	Aortic Regurgitation (AR)
<p>a) Acute: - Ischemia or infarction - Infective endocarditis Both → papillary muscle dysfunction or rupture of chordae tendinae - Functional MR due to LVD</p> <p>b) Chronic: - Rheumatic fever - Congenital</p>	<p>a) Acute: - Infective endocarditis. - Trauma - Aortic dissection</p> <p>b) Chronic: - Rheumatic - Congenital - Syphilis, cystic medial sclerosis ± Marfan syndrome, ankylosing spondylitis, rheumatoid arthritis → Aortic dilatation → AR.</p>
<p>• During systole → blood regurges to LA →</p> <p>• LAD → - Acute → pulmonary congestion and edema - Chronic → CHF</p> <p>• Low CO.</p> <p>During diastole → ↑ blood to LV →</p> <p>• Acute → no time for LVD or LVH</p> <p>• Chronic → ↑ LVEDV → maintaining normal CO, later → LVD and LVH</p> <p>So; LVF (with ↑ LVEDP + ↓ EF) → ↓ CO</p> <p>• Pan-systolic murmur on the apex propagated to the axilla</p> <p>• Amount of blood regurgitant via MV depends on</p> <ol style="list-style-type: none"> 1. Size of MV orifice 2. HR (systolic time) 3. LV – LA pressure gradient during systole which is affected by LV outflow <p>- ↓ systolic vascular resistance - ↑ LA pressure Both → ↓ regurgitant volume</p> <p>• Severity:</p> <p>If regurgitant fraction < 30% of SV → mild S & S If regurgitant fraction 30-60 SV → moderate S & S If regurgitant fraction > 60% SV → Severe S & S</p>	<p>• During systole → ejection of ↑ amount of blood</p> <p>• During diastole → blood regurges to LV →</p> <p>• ↓ SV → ↓ diastolic BP.</p> <p>• Acute → no time for LVD</p> <p>• Chronic → largest ↑ LVEDV of any heart disease → massive LVD called coreovinum.</p> <p>Both acute & chronic → LVF (with ↑ LVEDP + ↓ EF) → Pulmonary congestion →</p> <p>- Acute : pulmonary edema - Chronic : CHF</p> <p>• Early diastolic blowing murmur at the 2nd left intercostal space (2nd aortic area) + peripheral signs due to reflex peripheral VD → ↓ diastolic BP → e.g. bounding pulse.</p> <p>• Amount of blood regurgitant via AV depend on</p> <ol style="list-style-type: none"> 1. Size of AV orifice 2. HR (diastolic time) as ↓ HR → ↑ diastolic time → ↑ regurgitation. 3. Diastolic pressure gradient across AV (diastolic aortic pressure – LVEDP) So, ↑ diastolic BP → ↑ regurgitation. <p>• Severity:</p> <p>If regurgitant fraction < 30% of SV → mild S & S If regurgitant fraction 30-60 % of SV → moderate S & S If regurgitant fraction > 60 % of S.V. → severe S & S</p>
<ol style="list-style-type: none"> 1. Medical: Diuretics, digoxin, ACEIs & vasodilators → ↓ SVR → ↓ regurgitation volume → ↑ SV 2. Surgical: Valve replacement 	<p>.....As MR</p>

Monitoring (In all)

Standard +

1. Invasive ABP
2. CVP
3. Pulmonary A.P.
4. Tans-esophageal echocardiography

Anesthetic Management: In stenotic lesions maintain normotension & normal HR

ANESTHESIA WITH CARDIOVASCULAR DISEASES

	MS	AS
Aim	<p>1. HR: maintain sinus rhythm optimally between 60-90/min</p> <ul style="list-style-type: none"> * Avoid AF as it impairs ventricular filling so needs immediate cardioversion. * Avoid tachycardia as..... * Avoid bradycardia as..... <p>2. ABP: maintain normal BP (i.e. normal after load)</p> <ul style="list-style-type: none"> * Avoid hypotension (& VD drugs) as → severe hypotension → ↓ CO → ↓ Coronary perfusion <p>3. Fluid: maintain adequate blood volume (preload)</p> <ul style="list-style-type: none"> * Avoid hypovolemia as → severe hypotension. * Avoid hypervolemia (central blood volume ↑) as → ↑ pulmonary congestion. This can occur in over fluid transfusion, head down position, auto transfusion during uterine contraction in labor <p>4. Contractility: support usually is not needed</p> <p>5. Others: Avoid hypoxemia, hypercapnia, and acidosis</p> <p>(As → pulmonary VC → immediate RVF especially if with preexisting P⁺⁺). N.B.; In patients with multiple valvular lesions, there may be contradictory anesthetic goals (e.g. AR or MR with AS) So, always give the highest priority to the AS.</p>	
Choice of Anesthesia	<p>- Can be used in mild and moderate lesions with care to avoid hypotension.</p> <p>- Epidural is preferable to spinal anesthesia due to the more gradual onset of sympathetic block.</p>	
a) Regional		
b) GA	<ul style="list-style-type: none"> • Induction: <ul style="list-style-type: none"> - Slow smooth induction (↓ stress response to intubation.....) - Etomidate is of choice, thiopentone in a small dose can be used, ketamine is avoided • Maintenance: <ul style="list-style-type: none"> - If good ventricular function → Volatile based anesthesia. - If bad ventricular function → opioid based anesthesia. • Volatile agents: Halothane is of choice because it ↓ HR with least VD effect but others → more VD • N₂O: is used cautiously as ↑ PVR → P⁺⁺ So, it is avoided in patient with severe P⁺⁺ • Muscle relaxants: -Vecuronium or atracurium are of choice <ul style="list-style-type: none"> - Avoid pancuronium as → ↑ HR - The reverse is better with glycopyrrolate (than atropine). • Intraoperative fluids: should be carefully estimated and replaced. • Patient position: avoid head down position as → ↑ central blood volume. • Intraoperative complications: <ol style="list-style-type: none"> 1. Tachycardia: treated by <ul style="list-style-type: none"> • Deepening the anesthesia • i.v Esmolol • cardioversion (in case of severe supraventricular tachycardia) • Opioid (except pethidine) • i.v. digitalis (if with AF) 0.25-0.5 mg over 10 min 2. Bradycardia treated by • Atropine if severe 3. Hypotension treated by • Phenylephrine (pure α agonist) better than ephedrine or dopamine (α & β agonist) as both have β action so; they affect heart contractility & ↑ HR) 4. Hypertension treated by • potent vasodilators with full hemodynamic monitoring 5. P⁺⁺ & RVF treated by • inotropic support e.g. dopamine <ul style="list-style-type: none"> • Pulmonary VD e.g. nitroprusside. • Postoperative: ↑ risk of pulmonary edema and RVF due to sympathetic (+) caused by pain, hypoventilation (→ respiratory acidosis) and hypoxemia → pulmonary VC So, careful monitoring + O₂etc. <p>NB. In AS only: If cardiac arrest occurs, external cardiac massage is ineffective because it is difficult to create an adequate stroke volume across a stenotic valve so, a defibrillator should always be available if anesthesia is given.</p>	

In incompetent valve lesions maintain **slight hypotension & slight tachycardia**.

MR	AR
1. HR : maintain HR optimally between 80-100/min (except if with MS or AS) * Avoid tachycardia as \rightarrow ischemia * Avoid bradycardia as \rightarrow \uparrow regurgitant volume. 2. ABP : maintain slight hypotension (vasodilators are useful) * Avoid hypertension as \rightarrow \uparrow regurgitant volume. 3. Fluid : maintain it * Avoid hypervolemia as \rightarrow LVD \rightarrow \downarrow LV contractility. * Avoid severe hypovolemia as \rightarrow \downarrow ventricular filling volume \rightarrow \downarrow CO 4. Contractility : support may be needed . * Avoid drug induced decreased Contractility 5. Others: as MS and AS.....	
Both spinal and epidural blocks are well tolerated If the patient has good ventricular function Especially in TR, exclude coagulopathy due to liver affection.	
• Induction : Ketamine can be used • Maintenance : - If good ventricular function \rightarrow volatile based especially isoflurane as \rightarrow VD and Slight \uparrow HR - If bad ventricular function \rightarrow opioid based • N_2O : cautiously as \uparrow PVR, and if used with opioids \rightarrow severe myocardial depression • Muscle relaxant: pancuronium is of choice as \rightarrow slight tachycardia • Intraoperative complications : 1. Bradycardia treated by i.v. atropine 2. Hypotension treated by: Ephedrine (α and β agonist) is better than phenylephrine (pure α agonist) but avoid large doses of vasopressors as \rightarrow \uparrow SVR \rightarrow \uparrow regurgitant volume. 3. Hypertension treated by: Vasodilators..... 4. LVF treated by • Inotropic support e.g. dopamine • Systemic VD e.g. nitroprusside. NB. Especially in TR, avoid i.v. infusion of air bubbles via tubing during fluid administration due to a possibility of right to left shunt \rightarrow paradoxical systemic embolism .	

N.B; MR, dilated cardiomyopathy, and heart failure have nearly the same anesthetic management because the three diseases have poor LV function.

Mitral Valve Prolapse (Click Murmur Syndrome) (Floppy Valve Syndrome)

Causes:

1. Familial: 5-10 % of population especially ♀. It is **the most common valvular heart disease**.
2. Connective tissues disorders e.g. Marfan's syndrome.

N.B.; • Hereditary (familial) disease: It is gene related i.e. autosomal recessive, dominant, or x-linked.
 • Congenital or developmental disease: It is due to the presence of pathology during intrauterine period e.g. diabetes or drugs.

Pathophysiology:

- There are abnormalities of the MV support structure i.e. myxomatous proliferation which causes thickening and redundancy of the MV. This leads to prolapse of the MV into the LA during LV contraction.
- It may be asymptomatic up to florid MR.
- It is accentuated by a decreased ventricular volume (i.e. decreased preload).
- Complications:
 - 1) Atrial arrhythmias (PSVT is the commonest) and ventricular arrhythmias (PVCs is the commonest).
 - 2) Infective endocarditis.
 - 3) Acute MR.
 - 4) Embolic phenomenon e.g. transient ischemic attacks.
 - 5) Heart block.
 - 6) Sudden death (rare).

ANESTHESIA WITH CARDIOVASCULAR DISEASES**Diagnosis:**

- Mid systolic click at the apex \pm late systolic murmur.
- Echocardiography (the best).

Anesthetic Management:

Aim is to: Avoid decrease in ventricular size so;

- Avoid decreased preload (hypovolemia) because this causes greater systolic displacement of the leaflets into the LA.
- Avoid sympathetic stimulation by, decreasing anxiety, using short acting β blockers to avoid tachycardia.....etc.
- Avoid decreased afterload (SVR) by, using vasopressors.
- Avoid anesthesia in head up or sitting position.

Choice of Anesthesia:

- Regional anesthesia: is avoided because it may lead to hypotension (decreased SVR).
- General anesthesia:.....the same anesthetic management as MS i.e. keep normal ABP and heart rate except if MR occurs, the patient is managed as MR i.e. keep slight hypotension and tachycardia.

Pulmonary Hypertension and Cor Pulmonale**Definition:****Pulmonary Hypertension:**

Mean pulmonary arterial pressure (PAP) > 20 mm Hg at rest.

& > 30 mm Hg with exercise.

Cor Pulmonale:

Pulmonary hypertension-induced impairment of RV structure (hypertrophy and dilatation) and function.

Causes:**A- 1ry Pulmonary Hypertension:**

Pathology: - It is associated with other vasospastic conditions as Raynaud's phenomenon, Prinzmetal angina, or migraine headache.

- It may be associated with advanced liver disease where vasospastic compounds bypass liver degeneration.
- It occurs usually in ♀ around 30 years of age.

B- 2ry Pulmonary Hypertension:

Lung parenchyma		Lung vasculature		Chest wall	
Obstructive	Restrictive	Precapillary	Postcapillary	Intrinsic	Extrinsic
- COPD - Cystic fibrosis	- Sarcoidosis - TB	- Recurrent emboli - Schistosomiasis - High altitude - Hypoxia - Left to right shunt congenital heart disease as ASD or VSD	- MV diseases & LVF - LA myxoma - Veno-occlusive disease	- Kyphoscoliosis - Thoraco-plasty - Pectus deformity	- CNS disorders - Poliomyelitis - Sleep apnea syndrome

Pathophysiology:**• Normal pulmonary circulation;**

- It accommodates nearly the whole flow of the systemic circulation (\approx 5 L/min at rest and up to 25 L/min during heavy exercise), while operating at 1/6 of the systemic pressure.
- Pulmonary systolic BP = 22 mm Hg, diastolic BP = 10 mm Hg and mean BP = 15 mm Hg.

- The quantity of blood within the pulmonary circulation is $\approx 0.5-1$ L, while only 80 mL (\approx one cardiac SV) are exposed to the gas-exchange surface of the pulmonary capillaries at any specific moment.

• **RV response:**

Pulmonary hypertension leads to RV dysfunction, the rate at which RV dysfunction (and CHF) develop depends on the magnitude of the increased pressure in the pulmonary circulation and on the rapidity with which this increase occurs.

- Acute increase in PAP e.g. pulmonary embolism causes RVF with a mean PAP as low as 30 mm Hg, as increased PAP causes RV distension. This increases the wall tension to a failure threshold {La Place law is the wall tension (T) = radius (r) x intraventricular pressure (p)}.

- Chronic increase in PAP e.g. COPD allows time for RV hypertrophy (as a compensatory mechanism). This causes late RV failure which usually occurs when the mean PAP exceeds 50 mm Hg. Acute RVF occurs when a COPD patient is subjected to stress as infection, hypoxia, acidosis or fluid overload.

C/P:

History: - Asymptomatic.

- Symptoms of congestive heart failure (CHF) as cough, dyspnea, fatigue.....
- Symptoms of low CO as exertional dyspnea, syncope.....
- Symptoms of the cause as COPD.....

Examination:

- CHF as a prominent a wave, increased pressure of jugular venous pressure and pedal edema.
- RVH as S4, parasternal heave along the left sternal border and possible pulmonary and tricuspid regurgitation murmurs.
- Pulmonary hypertension causes accentuated pulmonary component of S2.

Investigation:

a- **ECG:** shows RVH, RAH and low voltages of QRS complexes in all leads (due to COPD).

b- **X-ray chest:** shows - RV or RA enlargement.

- Pulmonary hypertension causes;
 - Decreased pulmonary vascular markings.
 - Dilatation of the main pulmonary artery and central branches with possible calcification.

c- **Echocardiography:** shows RVH, PR, TR and dilatation of the pulmonary artery.

d- **Cardiac catheterization:**

- It differentiates RV dysfunction 2ry to LVF from that 2ry to pulmonary hypertension.

e- **Pulmonary function tests and arterial blood gases:**

To detect restrictive or obstructive lung disease.

Treatment: (of pulmonary hypertension and RVF)

1- **O₂ therapy:** - To maintain PaO₂ > 60 mm Hg or SaO₂ > 90 %.

- Avoid excessive O₂ in COPD when the hypoxic drive is predominant.

N.B.; An alternative to O₂ is **almitrine** which is a carotid body stimulant that improves ventilation-to-perfusion matching without affecting minute ventilation.

2- **Anticoagulant** (warfarin or antiplatelet): to prevent pulmonary emboli.

- **Antibiotic:** the commonest organisms are Hemophilus or Pneumococcus which are usually sensitive to ampicillin or cephalosporins.
- **Bronchodilators.**
- **Correction of electrolyte imbalance.**

ANESTHESIA WITH CARDIOVASCULAR DISEASES**3- Treatment of RVF:**

- Avoid volume overload as it increases RVEDV.
- Digitalis: is given with care due to the increased risk of toxicity in presence of arterial hypoxemia, acidosis and electrolyte disturbances.
- Diuretics: are given with care due to the following effects;
 - Metabolic alkalosis which decreases ventilation by depressing the effectiveness of CO₂ as a stimulus to breathing.
 - Increased blood viscosity causes further increase in Hct.
- Inotropic agents: dobutamine is better than dopamine because dobutamine lacks α action induced pulmonary VC.
- Phosphodiesterase III inhibitors: they are inotropic and cause VD as milrinone and amrinone.
- Intra-aortic balloon pump.

4- Treatment of pulmonary hypertension:**By vasodilators.**

Types; a- Non-specific pulmonary vasodilators;

- | | |
|---------------------------------------|------------------------------|
| • Hydralazine | systemic VD >>> pulmonary VD |
| • Na Nitroprusside | systemic VD > pulmonary VD |
| • Nitroglycerine | systemic VD > pulmonary VD |
| • Nifedipine | systemic VD > pulmonary VD |
| • Isoprenaline | systemic VD = pulmonary VD |
| • Prostaglandin E ₁ | systemic VD = pulmonary VD |
| • Tolazoline especially in pediatrics | |
- b- Specific pulmonary vasodilators;
- Inhaled nitric oxide.
 - Inhaled prostacyclin (PG I₂).

Side effects: (especially with nonspecific agents)

- Systemic hypotension.
- Decreased coronary perfusion which may lead to RV ischemic failure.
- They attenuate the localizing hypoxic pulmonary VC reflex so; worsen V/Q matching.

Anesthetic Management (Avoid sympathetic stimulation and histamine release)**Preoperative Management:**

1- Preoperative evaluation: History, examination and investigation (+ routine) as before.

2- Preoperative treatment of corpulmonale..... as before.

So; postpone elective surgery till properly treated to correct the reversible changes.

3- Preoperative correction of Hct:

- Chronic hypoxia causes 2ry polycythemia (Hct > 60 %) which in turn increases blood viscosity. This decreases O₂ carrying capacity and O₂ delivery to the tissues.
- So; decrease Hct to 50-55 % by euvolemic erythrophoresis or phlebotomy.
- Value: - It decreases blood viscosity.
 - It causes a small (2-3 mm Hg), but significant decrease in PAP.
 - It causes a small (0.3 L/min/m²), but significant increase in cardiac index.
 - It causes little (18 %), but significant increase in renal plasma flow.

4- Premedications:

- Avoid sedatives and opioids as they might depress respiration. They are replaced by psychological support.
- Avoid anticholinergics due to - Increased physiologic dead space.
 - Increased HR.

- Depressed mucociliary function which decreases clearance of secretions.

Intraoperative Management:

Monitoring:standard +

- Trans-esophageal echocardiography.
- Invasive arterial line: for ABP and blood gases.
- CVP: a sudden increase in CVP (RAP) indicates RVF.
- PA catheter to detect RV and LV function.
- Nerve stimulator to allow smooth recovery.

Choice of Anesthesia:

a- Regional Anesthesia:

Advantages:

- It avoids the effects of GA on respiration (e.g. decreased FRC, and ciliary activity, and increased V/Q mismatching).

Disadvantages:

- It is not suitable for upper abdominal surgery which requires a high sensory level of anesthesia which decreases SVR while PVR is still high due to the pulmonary hypertension so; this leads to severe systemic hypotension.

b- General Anesthesia:

Aim:

1. Avoid increased PVR.
2. Avoid sympathetic stimulation.
3. Avoid hypoxia, hypercarbia, acidosis, and hypothermia.

Induction:

Smooth induction with;

- **Preoxygenation** 100 % O₂ for 5 min.
- **Decreasing the pressor response** to intubation by
- No single agent is proved to be superior to another. So, a small dose of thiopentone can be given (**avoid ketamine** because it increases PVR).
- Avoid muscle relaxants causing **histamine release** as suxamethonium, atracurium, metocurine and d-tubocurarine. So, **the best is vecuronium**.

Maintenance:

A deep plane of anesthesia should be maintained to blunt sympathetic responses to surgical stimuli.

- * **Volatile agents:** All are bronchodilators, so they are used safely.
- * **N₂O:** It is avoided because it increases pulmonary VR. If it is used, it must be associated with close monitoring of its pulmonary effects.
- * **Opioids:** - **Avoid large doses** as they may produce postoperative respiratory depression.
 - **Avoid morphine** as it may produce histamine release.
- * **Muscle relaxants:-** Avoid relaxants causing histamine release.
 - Vecuronium is of choice.
- * **IPPV:** - It improves oxygenation despite increasing the PVR.
 - **Avoid hyperventilation** as it causes hypocapnia which in turn causes 2ry hypokalemia. The later precipitates digitalis toxicity.
 - All inspired gases must be warmed and humidified.

Intraoperative Complications:

Vasodilator therapy may be needed.

ANESTHESIA WITH CARDIOVASCULAR DISEASES**Recovery and Extubation:**

Smooth recovery is needed with proper returning of muscle activity (by nerve stimulator).

Postoperative Management:

Close monitoring to avoid complications as; RVF, ischemia, and respiratory failure.

Cardiomyopathy

Definition:

It is a diverse group of disorders characterized by **myocardial dysfunction** unrelated to the usual cause of the heart disease.

	Hypertrophic obstructive cardiomyopathy (HOCM) = Asymmetric septal hypertrophy = Idiopathic Hypertrophic Subaortic Stenosis (IHSS)	Dilated cardiomyopathy	Restrictive cardiomyopathy	Obliterative cardiomyopathy
Cause	1. Hereditary. 2. Chronic hypertension.	1. Diffuse coronary artery disease (the most common). 2. Alcohol abuse. 3. Toxic drugs cocaine, daunorubicin, and doxorubicin. 4. Viral or bacterial infection. 5. Other diseases as; - Sarcoidosis. - Muscle dystrophy. - Myotonic dystrophy. - Pheochromocytoma. - Acromegaly. - Thyrotoxicosis. - Myxedema. 6. Peri partum (up to 6 weeks after the delivery). 7. Idiopathic.	Infiltration of the myocardium by abnormal material as : * Amyloidosis. * Hemochromatosis * Glycogen storage disease.	Eosinophilic infiltration of multiple organs (Hyper-eosinophilic syndrome).
Pathology	* Hypertrophy of the LV and usually asymmetrical hypertrophy of the IV septum causing; a) Outflow obstruction of the LV - It is a dynamic obstruction i.e. reaches peak in mid-to late systole and varies with heart beats (in contrast to fixed obstruction of AS). - The obstruction leads to; • Increased LVEDP. • Decreased CO. b) MR due to interference with the movement of the MV leaflet by the hypertrophied interventricular septum. * C/P: - Asymptomatic. - Angina. - Exertional dyspnea, syncope. - CHF. - Arrhythmias e.g. AF, sudden death. - Harsh systolic murmur which shows marked variation with	* Biventricular dilatation causes; - Functional MR, TR. - CHF. - Hypokinetic LV with angina, ST and T wave changes. - Formation of mural thrombi which may cause systemic embolization. - 1 st degree heart block. - Arrhythmias as PVCs, AF..... - Death in 75 % of cases.	* Decreased ventricular compliance (due to thickened endocardium) which causes; - Impaired diastolic filling which results in decreased CO (as constrictive pericarditis). - Arrhythmias. - Conduction disturbances. - Systemic embolization. - MR and TR.	

	valsava maneuver, nitroglycerine and standing- hypotension.		
Hemo- dynamics	- LV contractility (& CO): ↑ - EF: ↑↑ - SV: Normal or ↑	- ↓ - ↓↓ - ↓↓	- ↓ - N or ↓ - N or ↓
Treatment	A. Factors decreasing outflow obstruction (factors maintaining LV size): 1. Decreased contractility: * β blockers. * Ca^{++} channel Blockers e.g. verapamil. So, volatile anesthetics are good. * Disopyramide. 2. Increased preload: * Hypervolemia. * Bradycardia. 3. Increased afterload: * α agonists. * Hypervolemia. B. Treatment of AF by amiodarone, cardioversion, and anticoagulant. C. Myomectomy or myotomy by CPB.	1. Treatment of the cause: e.g. * Total abstinence from alcohol. * Immunosuppressive treatment as corticosteroids, azathioprine. * Coronary revascularization. 2. Avoid unnecessary physical activity. 3. Treatment of CHF by digoxin, diuretics, inotropes, and vasodilators. 4. Treatment of arrhythmias. 5. Anticoagulant e.g. warfarin. 6. Cardiac transplantation.	- No effective treatment is present. - Treatment of complications as CHF and arrhythmias.
Anesthetic Management	As AS	As MR or heart failure.	As cardiac tamponade

Heart Failure (HF) (Congestive HF)

Definition: Inability of the heart to pump a sufficient amount of blood to meet the body's metabolic requirements (systolic dysfunction).

Causes:

a) LVF:

- * Valvular heart disease.
- * Ischemic heart disease (myocardial infarction).
- * Cardiomyopathy.
- * Systemic hypertension.
- * Pericardial disease.
- * Severe arrhythmias.

b) RVF:

- * 2ry to LVF.
- * Cor pulmonalesee before.
- * RV ischemia or infarction.

N.B.;

• **Biventricular Failure:**

It can occur if there is fluid overload and hypoalbuminemia. e.g. renal or hepatic disease.

• **High CO Failure:**

It can occur in hypermetabolic (hyperdynamic) states (with decreased SVR) e.g. sepsis, fever, thyrotoxicosis.

• **Low Fixed CO Failure:**

It is the limited or even absent ability to increase CO in response to VD, exercise or stress. This results in a picture of low CO.

ANESTHESIA WITH CARDIOVASCULAR DISEASES

It is the common end point of pulmonary hypertension, pulmonary embolism, severe pump failure, complete heart block, constrictive pericarditis, acute cardiac tamponade, AS, MS and PS.

Adaptive Physiologic Mechanisms:

1- Frank-Starling Mechanism:

- Significant impairment of ventricular diastolic function produces ventricular dilatation (RV dilatation does not necessarily occur). This increases VEDV which in turn increases VEDP (because the tension developed by the contracting muscle is greater when the resting length of that muscle is increased).
- Increase in VEDV results in an increase in SV which in turn increases CO.
- Also, increased VEDV stimulates atrial mechanoreceptors which in turn stimulate the SA node resulting in increased HR.
- Finally, when HF ensues, the myocardial fibers are unable to generate any further increase in the force of contraction leading to decreased SV and rapid decrease in CO.

2- Myocardial Hypertrophy and Cardiac Dilatation:

- Myocardial Hypertrophy (alone):

It is a compensatory mechanism that develops in response to chronic **pressure** overload i.e. afterload (AS, pulmonary hypertension, systemic hypertension). So, the ratio of the ventricular wall tension to the ventricular radius is increased. This means, that in a failing heart, there is an increase in the radius which increases wall tension. Myocardial hypertrophy increases myocardial contractility which in turn increases SV. This causes increased CO.

Laplace's law states that; $\text{Wall Tension} = \frac{\text{Pressure} \times \text{Radius}}{2 \times \text{Wall thickness}}$

- Cardiac Dilatation:

It is a compensatory mechanism that develops in response to chronic **volume** overload (MR, AR), later on hypertrophy occurs. So, the ratio of ventricular wall tension to ventricular radius is unchanged. Cardiac dilatation increases SV and CO according to Frank-Starling's mechanism.

- Finally, Myocardial hypertrophy (increased muscle bulk) and cardiac dilatation (increased wall tension according to the law of Laplace) increase myocardial O₂ demand. Both decrease cardiac efficiency.

N.B.; Acute severe afterload changes (severe systemic hypertension or severe pulmonary VC) may cause ventricular distension. This increases wall tension to a failure threshold (according to law of Laplace $T = P \times r$ (T = ventricular wall tension, P = intraventricular pressure, and r = radius of chamber) with subsequent acute LV or RVF.

3- Sympathetic Nervous System Activity:

- There is increased sympathetic activity due to increased norepinephrine release from nerve endings or adrenal medulla. This results in;

1. Increased HR and Contractility:

- Increased contractility i.e. increased velocity of contraction is developed by the cardiac muscle and the maximum velocity of contraction (V max).

- Increased HR:

* It is accompanied by increased contractility this is known as the **rate-treppe phenomenon**.

* In the presence of CHF and low basal CO, the SV is relatively fixed. So, increased HR results in increased CO (CO = HR x SV).

2. Arteriolar Constriction:

- It serves to maintain ABP despite a decrease in CO, but actually it causes more ventricular dysfunction.

- It causes redistribution of blood from the kidneys, splanchnic organs, skeletal muscles and skin so as to maintain cerebral and coronary blood flow despite a decrease in CO.

3. Venous Constriction:

- It shifts blood from the peripheral sites to the central circulation. This increases VR and maintains CO by Frank-Starling mechanism.

- Finally, chronic activation of the sympathetic system leads to;

* Catecholamine depletion.

* Decreased adrenergic receptors numbers (Down-regulation).

* Decreased adrenergic receptors response to catecholamines (CAs) i.e. decreased sensitivity.

So, the failing heart becomes dependent on circulatory CAs.

On abrupt withdrawal of sympathetic outflow or decreased circulatory CAs (as during induction of anesthesia), acute cardiac decompensation occurs.

4- Hormonal Mediated Responses:

• Renin-Angiotensin System:

- Decreased CO try to ventricular dysfunction decreases renal blood flow. This stimulates β_1 receptors which in turn stimulates the renin-angiotensin system. The latter causes;

• Increased angiotensin II which produces VC therefore, a further increase in afterload occurs with further deterioration of HF.

• Try increased aldosterone which produces Na^+ and H_2O retention, therefore, the blood volume increases and improves pump function initially through Frank-Starling mechanisms.

• Anti-Diuretic Hormone (ADH):

- With right sided HF, systemic venous congestion shifts H_2O from the intravascular compartment to the interstitial compartment. This causes edema formation and increases plasma osmolarity. The latter stimulates osmo-receptors in the hypothalamus which secretes ADH. ADH causes H_2O retention, increases blood volume, and improves pump function initially by increased VR through Frank-Starling mechanism.

• Atrial Natriuretic Peptide (ANP):

- It is stored in atrial muscles and released in response to increased atrial pressure and increased atrial distension (as produced by tachycardia and hypervolemia). It causes;

1. Potent vasodilatation which antagonizes the effect of angiotensin II.

2. Increased GFR which produces natriuresis and diuresis.

3. Decreased aldosterone and ADH secretion.

C/P:

Severity (Classification):

New York Heart Association (NYHA) Classification:

It is determined by symptoms (mainly dyspnea and fatigue).

- Class I: No symptoms i.e. no limitation of physical activity.

- Class II: Symptoms with ordinary activity i.e. slight limitation of physical activity.

- Class III: Symptoms with less than ordinary activity i.e. marked limitation of physical activity.

- Class IV: Symptoms at rest i.e. the patient can not do any physical activity without discomfort.

I – Low CO Symptoms (in Both Left and Right HF):

Relate these symptoms with the level of activity.

Muscle: fatigue, weakness, and exhaustion.

CNS: Dizziness, syncope, and confusion.

ANESTHESIA WITH CARDIOVASCULAR DISEASES

Kidney: Oliguria (pre-renal azotemia characterized by a disproportionate increase in BUN relative to s. creatinine).

Heart: Angina pectoris.

II – Left Ventricular Failure:**a. Pulmonary Venous Congestion:**

- Dyspnea (exertional then at rest), orthopnea, paroxysmal nocturnal dyspnea, and dry non-productive cough.
- Acute pulmonary edema starting with fine basal rales.
- Tachypnea, and cyanosis.

b. Left Cardiac Signs:

- Tachycardia.
- S₃ gallop.
- Murmurs of MR, AS or AR.

c. Symptoms of the Cause e.g. chest pain.**III – Right Ventricular Failure:****a. Systemic Venous Congestion:**

1. Peripheral edema (dependent and pitting).
2. Jugular venous distension with a prominent a wave.
3. Hepato-jugular reflux.
4. Hepatomegaly with right hypochondral pain and tenderness.
5. Kussmaul's sign: As during inspiration, there is an increase in the jugular venous distension and pressure (normally during inspiration, there is increased -ve intra-thoracic pressure which propels jugular blood to the pulmonary circulation easily resulting in collapse of jugular venous pressure). This occurs also in constrictive pericarditis and cardiac tamponade.

b) Right Cardiac Signs:

- Para-sternal heave along the left sternal border.
- Increased pulmonary component of S₂ and S₄ gallop.
- Possible murmur of TR and PR.

c) Symptoms of Cause:

E.g. - LVF (the most common cause)

- Underlying pulmonary disease as dyspnea, cough, and expectoration.

Assessment of Cardiac Function:

1. Tissue Perfusion Assessmentsee before in monitoring.
2. Central Venous Pressure Assessment..... see before in monitoring.
3. Pulmonary Artery Catheter (for derived hemodynamics)..see before in monitoring.
4. CO Measurement..... see before in monitoring.
5. Transesophageal Echocardiography..... see before in monitoring.

N.B.: Criteria of Significant Ventricular Dysfunction:

1. LV EF (SV/ EDV): < 50 % (0.5). Normally: 55-77 %.
2. LV ED pressure: > 18 mm Hg. Normally: LV < 12 mm Hg, RV < 5 mm Hg
3. Cardiac index: < 2.2 L/min/m².

Anesthetic Management:**Preoperative Management:****Preoperative Evaluation:**

- 1- **C/P:** by history and examination..... as above.

2- Preoperative Investigation:**1. Chest X-ray:** It gives an idea about;

- * The size and shape of the cardiac shadow.
- * The underlying disease.
- * Radiographic signs of LVF.
 - The earliest sign is pulmonary venous congestion in the upper lobes of the lungs.
 - Pleural and pericardial effusion (especially if biventricular failure is present).

2. Twelve-Lead ECG:

It shows the underlying cardiac disease.

3. Echocardiography:

It shows the underlying cardiac disease and severity of failure.

4. Cardiac Catheterization:

It shows the underlying cardiac disease and severity of failure.

5. Other Investigations:

Renal, hepatic, arterial blood gases ... etc.

3- Determination of Operative Risk:

- NYHA classes I or II: have only a slight risk of developing post-operative pulmonary edema.
- NYHA classes III or IV: have an extremely high risk.
- Elective surgery: should be postponed till adequately controlling the HF.
- Emergency surgery: requires transferring patients to a major medical centre where careful invasive monitors should be used to optimize the preload, afterload and left and right ventricular stroke work.

Preoperative Preparation:**(1) Treatment of HF:**

1. **Digitalis:** For action and side effects (.....see pharmacology).

Preoperative digitalis: It is better continued up to the time of surgery especially if the patient has AF with a ventricular rate > 80 / min.

2. **Dopamine / Dobutamine / Phosphodiesterase Inhibitors** (.....see pharmacology).

3. **Diuretics.** (.....see pharmacology).

4. **Vasodilators** (.....see pharmacology) especially nitroglycerine and nitroprusside.

5. Decrease Cardiac Workload:

- Decrease physical activity and emotional stress.
- Weight control.
- Mechanical assistance of the circulation (intra-aortic balloon pump counter – pulsation).

6. Improvement of Myocardial Pump Function:

- Pacemaker.

7. Control of Excessive Salt & H₂O Retention:

- Dietary restriction.
- Thoracocentesis, paracentesis, phlebotomy, or dialysis.

(2) Premedications:

- 1- Sedatives: Decrease the dose or even omit it to avoid ventilatory depression that may cause hypoxia which in turn increases pulmonary VC. Therefore, pulmonary hypertension increases resulting in more RVF.

- 2- Anticholinergics: They are omitted to avoid their tachycardiac effect.

Intraoperative Management:

Monitoring: as hypertensionsee before.

ANESTHESIA WITH CARDIOVASCULAR DISEASES**Choice of Anesthesia:****A. Regional Anesthesia:**

It is useful because the sympathetic blockade causes VD which decreases the pre- and afterload, but **avoid high blocks**.

B. General Anesthesia:**Aim:**

1. Avoid brady – or tachyarrhythmias.
2. Avoid a severe decrease in the preload and allow reduction of the afterload.
3. Avoid myocardial depression.
4. Avoid sympathetic stimulation.

Induction:

- **Preoxygenation** with 100 % O₂ for 5 min.

Induction Agents:

- * **Etomidate** is of **choice** as it has little effects on cardiac function.
- * Ketamine can be used, but in end-stage HF, the endogenous catecholamine stores are depleted and additional cardiac decompensation may occur after administration of ketamine due to its direct –ve inotropic effect.
- * **Large dose opioids** can be used as fentanyl 50 µg/kg i.v. or sufentanil 2-7 mg/kg i.v.
- **Muscle relaxants for intubation:**
 - * Use muscle relaxants that have less C.V.S effects as vecuronium or atracurium.
 - * In RVF (where pulmonary hypertension is present), avoid atracurium as it causes histamine release which produces pulmonary VC, with subsequent increased pulmonary hypertension and RVF.
 - * Avoid pancuronium as it causes sympathetic stimulation and increases arrhythmias.

Maintenance:

- **Volatile agents** are used **cautiously and in small doses** because:

- * They cause dose dependent myocardial depression (-ve inotropic effect).
- * They cause a greater myocardial depressant effect in the failing heart than in the normal heart (i.e. the failing heart is more sensitive to the depressant effect of anesthetics than the normal heart).
- **Opioids** as fentanyl or sufentanil can be used for maintenance **with small doses of ketamine**. Avoid using N₂O or small dose benzodiazepines as they cause severe myocardial depression.
- **N₂O** is better **avoided** and if it is used, it must be used very cautiously and with a PA catheter monitoring. Effect of N₂O.....as in hypertension.
- Muscle relaxant:as in hypertension.
- IPPV:
 - It decreases pulmonary congestion in LVF and improves oxygenation despite it increasing the PVR
 - **Avoid hyperventilation** (as it causes hypocapnia) which in turn leads to 2ry hypokalemia. The latter increases digitalis toxicity.

Intraoperative Fluid Management:

It should be done very carefully by **pulmonary artery catheter monitoring** to optimize LV filling pressure.

Intraoperative Complications:

C.V.S support: by

- * Inotropes: dopamine or dobutamine.

* Vasodilators: to decrease the afterload. Avoid severe hypotension because it decreases myocardial O₂ supply resulting in depressed cardiac function.

N.B.; Avoid calcium (as an inotrope) because it may precipitate digitalis toxicity.

Postoperative Management:

In ICU,

- O₂ supplementation.
- Prophylactic **ventilatory** support for 24-48 hours.
- Postoperative **pain control**.
- Continue C.V.S support till the patient is hemodynamically stable.

Shock

Definition:

Circulatory failure leading to inadequate vital organ perfusion and O₂ delivery.

Causes:

A. Hypovolemic Shock:

- 1- Loss of **blood** (Hemorrhagic shock) (intravascular volume deficit).
 - External hemorrhage e.g. trauma, GIT bleeding.
 - Internal hemorrhage e.g. hematoma, hemothorax or hemoperitonium.
- 2- Loss of **plasma** e.g. burn, exfoliative dermatitis.
- 3- Loss of **fluid** and electrolytes.
 - External: e.g. vomiting, diarrhea, excessive sweating, hyper-osmolar states (diabetic ketoacidosis, hyperosmolar non-ketotic coma).
 - Internal (3rd space) e.g. pancreatitis, ascitis, bowel obstruction.

B. Cardiogenic Shock (Pump Failure): → RVF and LVF.

1. **Dysrhythmias:** Brady- or tachyarrhythmias.
2. **Pump failure:** Myocardial infarction / myocarditis / cardiomyopathy.
3. **Acute valvular** dysfunction: especially regurgitant lesions.
4. **Rupture** of the ventricular septum or the free ventricular wall.

C. Obstructive Shock (of blood flow):

1. **Tension pneumothorax.**
2. Pericardial disease (**tamponade, constriction**).
3. Cardiac tumor (**atrial myxoma**).
4. Left atrial **mural thrombus**.
5. **Obstructive valvular** diseases as AS, MS.
6. Disease of the **pulmonary** vasculature (massive pulmonary embolism or pulmonary hypertension).

D. Hyperdynamic Shock (Vasogenic, Low resistance or Distributive) Shock:

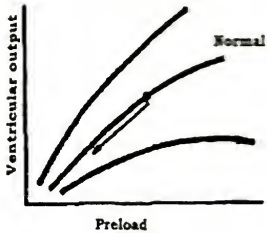
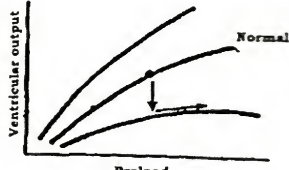
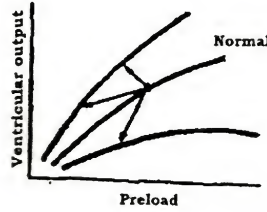
1. **Septic** shock.
2. **Anaphylactic** shock.
3. **Neurogenic** shock e.g. brain stem dysfunction.
4. **Vasodilator drugs**.
5. **Acute adrenal insufficiency**.

N.B.; Distributive shock describes the redistribution of intravascular volume to the interstitial and intracellular places causing decreased preload due to altered capillary permeability. It is included in the hyperdynamic shock group.

Q: What is the management of non-hemorrhagic shock?

A: All causes of shock except loss of blood causes.

Pathophysiology of Shock:

	Hypovolemic	Cardiogenic	Hyperdynamic
Starling curve			
1ry Defect	Decreased blood volume (preload).	Decreased contractility (associated with increased preload).	Decreased SVR (associated with decreased preload).
Compensatory mechanisms	Increased SVR.	Increased SVR.	Ventricular contractility and SV are variable.
In the decompensation stage; all parameters (preload, afterload [SVR], and contractility) are decreased in the terminal stages of all types of shock.			

Assessment of Shock:

1. Tissue perfusion.....see before monitoring.
2. CVP.....see before monitoring.
3. PCWP.....see before monitoring.
4. CO.....see before monitoring.

Guide Lines for Treatment of Shock:**1. Patient Resuscitation:**

.....ABC protocol

2. Treatment of the cause: e.g.

- Control blood loss in hypovolemic shock.
- Antibiotic in septic shock.
- Anti-allergic in anaphylactic shock.
- Anti-ischemic in cardiogenic shock.

3. Treatment of the 1ry Defect:**Assess CVP****Low**

So, the patient needs fluid therapy.

The response to a fluid bolus 250 mL is either;

- A small increase (1-2 mm Hg) indicating the need for more fluid.
- A large increase (> 5 mm Hg) indicating the need for a slower rate of infusion.

Normal or High

* PCWP < 15mm Hg * UOP Low * Cardiac index < 4.5 L/min/m ²	• PCWP > 15 mmHg * UOP Low * Cardiac index < 4.5 L/min/m ²	• PCWP > 15 mm Hg * UOP Low • Cardiac index > 4.5 L/min/m ²	• PCWP > 15-20 mm Hg • UOP high • Cardiac index > 4.5 L/min/m ²
Needs more fluid therapy	Cardiogenic shock Which is treated as before	High cardiac output shock which needs vasopressors	Hypervolemia Stop or decrease the

see heart failure.	if associated with low ABP "see septic shock". or bad kidney function which needs i.v. mannitol if there is high ABP.	rate of infusion.
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4- Treatment of Complications.

E.g. ARD Syndrome, DIC, or renal failure.

Hypovolemic Shock

Definition:as above**Causes:**as above**Compensatory Mechanisms:**

.....See cardiovascular physiology. (The same as control of arterial blood pressure).

Clinical picture:

	Grade I (Minimal)	Grade II (Mild)	Grade III (Moderate)	Grade IV (Severe)
- % of blood lost (in shock) or - % of body weight lost as water (in dehydration). 1% loss equals loss of 700 mL in a 70 kg body weight person.	10 %	20 %	30 %	> 40 %
- Pathophysiology	- Minimal change	- Decreased peripheral perfusion only of organs able to withstand prolonged ischemia (skin, fat, muscle and bone). - Arterial pH is normal.	- Decreased central perfusion of organs able to tolerate only brief ischemia (liver, gut, and kidney). - Metabolic acidosis.	- Decreased perfusion of the heart and brain. - Severe metabolic acidosis + respiratory acidosis may occur.
- C/P * HR (beat/min) * ABP (mmHg) * UOP (mL/hr) * Sensorium * Peripheral circulation * Mucous membrane (tongue). * CVP (cm H ₂ O) manubrium is zero reference. * Sunken eye (↓IOP) in dehydration only. * Skin turgor (elasticity) in dehydration only.	• Normal • Normal • Normal 1 mL/kg/hr • Normal • Normal & sweating • Dry tongue (thirst) • Normal • + • ↓	• 100-120 • Orthostatic hypotension • 20-30 concentrated • Normal + nausea & apathy. • Cold & pale + dry axilla & groin. • Very dry • (-3) collapsed neck veins. • ++ • ↓↓	• 120-140 (thready pulse) • Systolic < 100 + supine hypotension • 10-20 • Restlessness • Cold & pale + slow capillary filling • Very dry • (-5) • +++ • ↓↓↓	• > 140 (thready pulse) • Systolic < 80 • Nil • Impaired consciousness → coma → death • Cold & Calmy + peripheral cyanosis. • parched • (-8) • +++++ • ↓↓↓↓

N.B: Sunken eyes & decreased skin turgor need time to occur so, they are common with dehydration (subacute or chronic) rather than with hypovolemic shock (acute).

ANESTHESIA WITH CARDIOVASCULAR DISEASES**Investigation:**

1. Increased Hb concentration & Hct in dehydration due to hemoconcentration.
2. Decreased renal blood flow causes;
 - Increased BUN out of proportion to increased s. creatinine (prerenal uremia).
 - Stimulation of ADH & aldosterone causes;
 - Decreased urinary Na concentration < 20 mmol/L.
 - Increased urinary specific gravity > 1000 mmol/L.
 - Increased urinary osmolality.

Treatment of Hypovolemic Shock:**(1) Patient Resuscitation:**

.....Airway + Breathing + Circulation.

- Multiple large bore (14-16 gauge) cannulas are placed .
- Central line insertion: although it may provide useful information regarding the volume status, it is time-consuming and has life threatening complications e.g. pneumothorax. It can be introduced later.
- Patient position: supine and legs up (elevate feet of the bed).
- Pneumatic anti-shock garments (Military antishock trousers) are used to decrease bleeding in lower extremities and increase SVR. This helps perfusion of the heart and brain (only deflated when fluid volume is given).

(2) Fluid Therapy:

Its type depends mainly on the availability.

1- Blood:

- Fully cross-matched whole blood is ideal (typing and cross-matching take 45-60 min).
- Type specific blood (takes 5-10 min). It causes an antibody reaction in 1 % in ♂ and 2 % in parous ♀.
- Uncrossed O –ve packed RBCs should only be given in life-threatening blood loss that can not be adequately replaced by other fluids.

2- Crystalloid Solutions:**Advantages:**

- They can correct interstitial and intravascular fluid losses.
- They decrease blood viscosity which may enhance perfusion.
- They are readily available and economically effective.

Disadvantages:

- They leave the intravascular space and enter the interstitial space, large amounts are needed and they may cause both pulmonary and peripheral edema although studies have not confirmed occurrence of both types of edema.

Types:

- **Normal saline:** is suitable for ECF deficit especially interstitial fluid replacement.
- **Lactated Ringer's :** is less likely to cause hyperchloremic acidosis than normal saline, but its Ca^{++} content is less compatible with blood transfusion. It can treat patient's acidosis as lactate is metabolized to bicarbonate.
- **Hypertonic solution** (small volume resuscitator).
 - E.g.: 7.5 % saline (its osmolarity is 2400 mEq/L).
 - 3.0 % saline (its osmolarity is 1026 mEq/L).

Use: It has a role during emergency resuscitation especially in a pre-hospital setting and patients that can not tolerate edema formation e.g. closed head injury.

Action: 1. This small volume with high osmolarity **draws fluid** into the vascular compartment resulting in expanding plasma volume (every 1 mL of hypertonic saline increases plasma volume 3 mL).

2. It increases the preload and decreases the afterload by **VD** resulting in increased EF i.e. inotropic action.

Side effects: 1. It may cause **VD** and hypotension.

2. **Thrombophlebitis** so, it should be given in the central line only.
3. Mild to moderate **dilutional hypokalemia**.
4. **Hyperchloremic hypernatremia** (it should be stopped if s. Na^+ reaches > 160 mEq/L). It causes acidosis due to increased renal HCO_3^- loss 2ry to increased s. Cl^- .
5. **Cellular dehydration** which is useful in closed head injury.
6. Rapid i.v. infusion may cause **central pontine myelinolysis** (characterized by dysarthria, dysphagia, quadri- or paraparesis).

N.B.; Avoid dextrose containing solutions as they increase ischemic brain damage. Only given if there is documented hypoglycemia.

3- Colloid Solutions:

- They remain in the intravascular compartment for longer period.
- Albumin is better than dextran or starch as it does not cause coagulopathy.

N.B.; - All fluids should be warmed.

- The amount of fluid given should be based on clinical signs and CVP.

(3) Vasopressors:

- They are not given in hypovolemic shock except if there is severe hypotension not responding to aggressive fluid therapy. Some give low dose dopamine to increase renal blood flow.

N.B.; Causes of Persistent Hypotension :

- 1- Continued blood loss (external or internal): its rate exceeding the rate of fluid replacement. So, check platelets and clotting factors.
- 2- Presence of another undiagnosed type as;
Coexisting cardiogenic shock: as tamponade, or myocardial contusion.
Coexisting obstructive shock: as pneumothorax, or hemothorax.
Coexisting distributive shock: as septic shock, or neurogenic shock.
- 3- Coexisting metabolic problems: as acidosis ($\text{pH} < 7.1$), hypokalemia, or hypocalcemia.
- 4- Irreversible shock.

Cardiac Dysrhythmias

Mechanisms of Dysrhythmias:

Two electro-physiologic basis are involved:

A. Abnormality in Impulse Formation (= Abnormality in Automaticity)

- In the normal heart, the SA node functions as the pacemaker of the heart.
- Increased slope of spontaneous phase 4 depolarization (of SAN) causes enhancement of automaticity which in turn produces tachycardia and ventricular irritability leading to tachyarrhythmias (.....see causes of tachycardia).
- Decreased slope of spontaneous phase 4 depolarization (of SAN) decreases enhancement of automaticity of the SA node but increases enhancement of automaticity of lower pacemakers leading to bradyarrhythmias (.....see causes of bradycardia).

B. Abnormality in Impulse Conduction

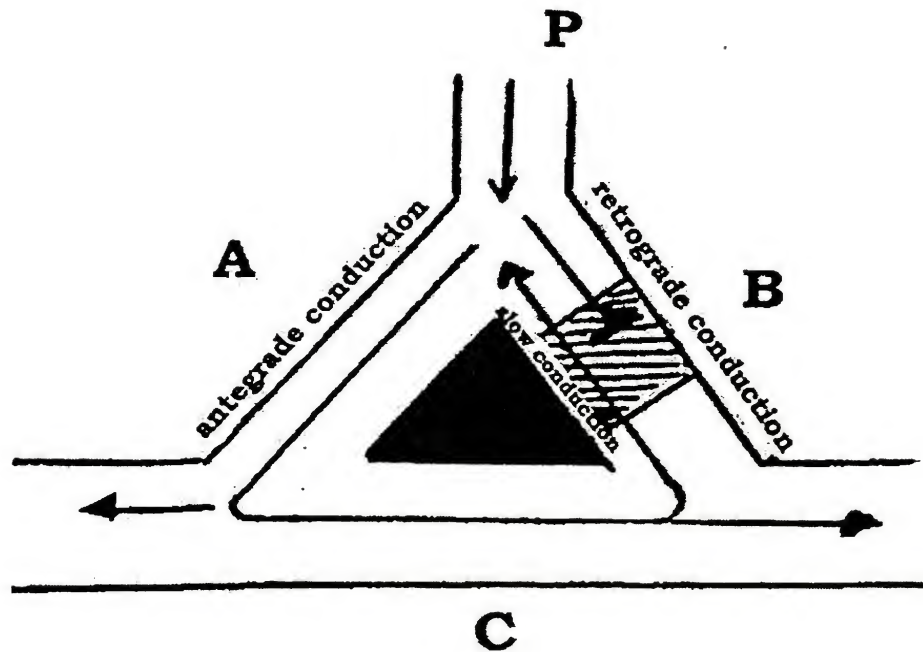
(Re-entry Pathway, Re-entry Excitation or Unidirectional Block)

It causes most of the tachyarrhythmias and premature beats (figure 9-2).

ANESTHESIA WITH CARDIOVASCULAR DISEASES

Four conditions are necessary to initiate and sustain re-entry:

1. Two areas in the myocardium that **differ in conductivity or refractoriness** and can form a **closed electrical circuit**.
2. **Unidirectional block in one limb (B)** due to a functional cause or scar tissue (i.e. **retrograde conduction**) while antegrade conduction occurs in the other limb (A).
3. **Slow conduction or sufficient length in limb B** to allow recovery of the conduction block (RP) in (A). This allows excitation to continue.



P = Purkinje fiber dividing into 2 limbs.
 A = Normal limb with antegrade conduction.
 B = Abnormal limb with retrograde (unidirectional) conduction.
 C = Ventricular muscle cell.

Figure 9-2; Re-entry pathway

4. When excitation of the limb with block (B) occurs, retrograde conduction occurs through this blocked limb. When the impulse returns to the limb showing antegrade conduction (A), it will already be repolarized i.e. **impulses reach limb A after effective refractory period** producing a **circus movement and sustained conduction**. Therefore, reciprocating tachyarrhythmias occur i.e. the impulses reciprocate between the atria and ventricles.

N.B.; Very rarely, circus movement occurs in an opposite direction i.e. antegrade conduction via the bypass tract and retrograde conduction via the AV node. This causes an abnormal QRS complex shape with a delta wave. So, it can be mistaken with ventricular tachycardia.

Factors initiating re-entry excitation:

- Hypoxemia.
- Hypercarbia.
- Acidosis.
- Digitalis.
- Myocardial ischemia.

N.B.; Dysrhythmias is a better term than arrhythmias because dys- = irregular, but a- = no.

Hemodynamic Effects of Dysrhythmias**1. Effect of Bradycardia:**

- It causes a serious decrease in CO especially in pulmonary hypertension, CHF, MS, MR, AS, and constrictive pericarditis.

2. Effect of Tachycardia:

- It decreases the time for diastolic filling of ventricles especially in MS producing a decrease in CO.

- It increases the tension time index and increases myocardial O₂ consumption especially in aortic valve diseases and ischemic heart diseases.

3. Effect of Ventricular Dysrhythmia:

- It causes less efficient contractions especially in AS, PS, pulmonary hypertension and systemic hypertension.

Classification of Dysrhythmias**A. Supra-Ventricular Dysrhythmias****I. Sinus Rhythm:****1. Sinus Bradycardia:**

ECG: Sinus i.e. P wave is +ve in lead II and -ve in aVR.

Each QRS complex is preceded by a P wave.

HR is < 60 / min.

Causes: due to decreased normal discharge of the SA node.

1. Physiologic: In athletes, it is a normal finding.

2. Pathologic:

- | | |
|---------------------------|---|
| - Hypothyroidism. | - Hypothermia. |
| - Increased ICP. | - After myocardial infarction. |
| - Acute hyperkalemia. | - Sleep apnea syndrome. |
| - Carotid sinus syndrome. | - Sick sinus syndrome (degenerative disease in SA node in the elderly). |

3. Intraoperative onset:

- A 2nd dose succinylcholine.
- Halothane.
- During laryngoscopy especially with a straight blade (as it touches the upper surface of the epiglottis which is vagally innervated).
- Traction on extraocular muscles (oculo-cardiac reflex), or mesentery.

4. Drugs:

- Digitalis
- Ca⁺⁺ channel blockers as verapamil, or diltiazem.
- Para-sympathomimetics (e.g. edrophonium).
- Sympatholytics (e.g. β blockers).

Treatment:

1. Treatment of the cause.
2. If it does not affect the hemodynamics, no treatment is given.
3. If it affects the hemodynamics;
 - a. Stop drugs which cause bradycardia as.....
 - b. Anticholinergics: atropine or glycopyrrolate.
 - c. If refractory bradycardia is present;
 - Isoprenaline (pharmacologic pacing) 0.5-8 μ g/min i.v. according to the response.
 - Electric cardiac pacing.

N.B.; An anticholinergic drug may be given prophylactically when surgical stimulation increases the risk of bradycardia e.g. ophthalmic surgery or 2nd dose suxamethonium.

ANESTHESIA WITH CARDIOVASCULAR DISEASES

Q: What are the causes of intraoperative bradycardia?

A: All the causes of bradycardia.

2- Sinus Tachycardia:

ECG: Sinus i.e. P wave is +ve in lead II and -ve in aVR.

Each QRS complex is preceded by a P wave.

HR is > 100 / min up to 180.

Causes: due to increased normal discharge of the SA node.

1. Physiologic: Exercise, anxiety, or pain (sympathetic stimulation).

2. Pathologic:

- | | |
|---------------------|-------------------------------|
| - Thyrotoxicosis | - Fever |
| - Hypovolemia | - Acute myocardial infarction |
| - Acute hypokalemia | - Pulmonary embolism |
| - CHF | |

3. Intraoperative onset:

- | | |
|-----------------------------------|--------------------------|
| - Light anesthesia | - Hypoxemia. |
| - Hypercarbia | - Acidosis |
| - Hypoglycemia | - Malignant hyperthermia |
| - Incompatible blood transfusion. | |

4. Drugs: - Sympathomimetics: epinephrine, ephedrine, isoproterenol
- Parasympatholytics: atropine.

Treatment:

1. Treatment of the cause.
2. If it is associated with hemodynamic effects especially myocardial ischemia, give β blockers as i.v. esmolol or propranolol.

Q: What are the causes of intraoperative tachycardia?

A: All the causes of tachycardia.

3- Sinus (Phasic, Respiratory) Dysrhythmias:

ECG: Sinus rhythm with an irregular rate with respiration

As inspiration (\downarrow vagal tone) causes a slight increase in the HR

and expiration (\uparrow vagal tone) causes a slight decrease in the HR

Cause: It is a normal physiologic state.

Treatment: No

NB. Sick Sinus Syndrome:

ECG: It needs 24 hours Holter ECG.

- Unexpected persistent severe bradycardia (the most common form).
- Episodes of sinus arrest.
- Paroxysmal supraventricular tachycardia.
- Paroxysmal or chronic atrial flutter or atrial fibrillation.
- Slow return to sinus rhythm after cardioversion.
- Lack of increased sinus rate > 90/min after i.v. 1.5-2 mg atropine.

Treatment:

1- Patients suspected to have sick sinus syndrome should be investigated before any elective surgery is done, and a decision is made as whether temporary or permanent cardiac pacing is necessary.

Indications of Pacemakers:

1. Severe symptoms.
2. Sick sinus syndrome patients with supraventricular tachycardia so, a temporary pacemaker should be placed before the usage of drugs which treat supra-ventricular

tachycardia e.g. digoxin, verapamil or β blockers, otherwise severe bradycardia occurs.

2- Long-term anticoagulants (by some authors).

II. Supraventricular Dysrhythmias:

1. Premature Atrial and Premature Junctional Beats:

ECG: The beat is premature i.e. earlier than expected and followed by a pause.
Abnormal shaped P wave or fused with the T wave of the preceding beat.
QRS complex is normal.

Cause: It arises from an ectopic pacemaker in the atrium or near the AV node.

1. Normally in persons with increased emotions or who drink excessive coffee.
2. Sympathomimetic drugs.

Treatment:

Increase the HR by i.v. atropine which usually abolishes them.

2. A.V. Junctional Rhythm (Nodal Rhythm):

ECG: • HR is either < 60 /min \rightarrow AV junctional escape rhythm.
or $100-250$ /min \rightarrow AV junctional tachycardia.

- The P wave is retrograde i.e. -ve in L_{II} and +ve in aVR.

i.e. atrial depolarization occurs in the opposite direction.

Cause: There is a continuous rhythm of a pacemaker which arises from the AV node or nearby tissues, usually occurring with **halothane anesthesia**.

Treatment:

- 1- Decrease halothane concentration or change to another volatile agent.
- 2- Atropine or glycopyrrolate i.v. if associated with significant hemodynamic changes.

3. Paroxysmal Supraventricular Tachycardia (PSVT) (Narrow Complex Tachycardia):

ECG: • Sudden onset and sudden offset of at least 3 or more consecutive premature S.V. beats, either non sustained ≤ 30 sec. or sustained > 30 sec.
• HR is $100-250$ /min & very regular.

Types:

a. Paroxysmal Atrial Tachycardia:

ECG: •.....as above

- Very regular (Unlike sinus tachycardia as the HR reaches $100-189$ /min and shows beat to beat variability).
- P wave: is different than normal.
- QRS complex: is normal.

Cause: There is a rapidly firing ectopic focus in the atrium especially with WPW syndrome or other pre-excitation syndromes.

b. A.V. Nodal Re-entrant Tachycardia:

ECG: •.....as above.

- P wave: is hidden in the QRS complex i.e. both atria and ventricles are activated simultaneously or a retrograde P wave is present.

Cause: There is a re-entry excitation phenomenon.

Treatment:

1. Treatment of the cause.
2. It may resolve spontaneously.
3. Increase the vagal tone by **carotid sinus massage** (unilateral on the right side, usually for 10-20 sec) or **Valsalva maneuver** (straining) in an awake patient.

ANESTHESIA WITH CARDIOVASCULAR DISEASES

If unsuccessful, give;

4. Adenosine 3-12 mg by fast i.v. injection (of choice).

- It has a duration of action < 60 sec. and blocks A-V conduction without compromising ventricular function so, it is safe and effective during hemodynamic instability. It is avoided in patients with asthma or AV conduction block.

5. If adenosine is unavailable;

& the patient is normotensive, give	& the patient is hypotensive or ischemic, perform
<p>1. Verapamil: 1-2 mg i.v. increments up to 10 mg or 75-150 µg/Kg over 1-3 min. Side effects:</p> <ul style="list-style-type: none"> • Prolonged hypotension. • Inhibition of ventricular function especially with anesthetic agents causing myocardial depression. • It is avoided in patients with β blockers as it causes refractory asystole. <p>2. Esmolol: 250-500 µg/Kg i.v. bolus over 1 min. & /or 100-300 µg/Kg /min i.v. infusion.</p> <p>3. Other drugs :</p> <ul style="list-style-type: none"> - Digitalis - Quinidine - Edrophonium - Procainamide - Propranolol - Phenylephrine (as it produces VC which in turn increases ABP causing a reflex increase in vagal tone. 	<p>1. Synchronized DC cardioversion</p> <ul style="list-style-type: none"> • Synchronized DC is done to avoid occurrence of a DC shock in the vulnerable period of ventricular repolarization (i.e. synchronization makes the shock occur simultaneously with an R wave apex), otherwise VF occurs. • 25-50 Joule. • Requires light general anesthesia.

6- Special Situations:

• **PSVT due to digitalis toxicity:**

- Avoid DC cardioversion as it may cause ventricular arrhythmias.
- It is treated by phenytoin 100 mg i.v. over 5 min + correction of hypokalemia.

• **Sepsis related or refractory PSVT:**

- Volume loading.
- Amiodarone 300 mg i.v. infusion over 20 min.
Then 900 mg i.v. infusion over 24 hours.

• **Thyrotoxicosis or pheochromocytoma:**

- β blockers.
- In pheochromocytoma, α blockers should be given first.

• **Recurrent A-V nodal re-entrant tachycardia:**

- Radiofrequency catheter ablation as a small burn near the A-V node is done to stop the circuit.

4. Atrial Flutter:

ECG: • **HR:** - Rapid atrial rate 300 beat/min.

- The ventricular rate is according to the degree of A-V conduction either 1:1 flutter i.e. 300/min,
2:1 flutter i.e. 150/min,
3:1 flutter i.e. 100/min,
or 4:1 flutter i.e. 75/min.

- P wave: is absent and replaced by the characteristic flutter waves (F-waves) producing a Saw – Tooth pattern.

Cause:as AF.

Treatment:as AF.

5. Atrial Fibrillation (AF):

ECG: • HR: - Rapid atrial rate 350-500 beat/min.

- The ventricular rate is extremely irregular but > 140 /min. with healthy A-V Junction.

- P wave: is absent and replaced by irregularities.
- It may be paroxysmal or chronic.

Complications:

- 1- Atrial thrombosis causing systemic embolization.
- 2- Low CO causing CHF, hypotension, and myocardial ischemia.

Causes:

1. **Valvular** heart disease.
2. Chronic myocardial **ischemia** or acute myocardial **infarction**.
3. **Hypertensive** heart disease.
4. **Cardiomyopathy**.
5. **Lung** disease or pulmonary emboli.
6. After **cardiac surgery**.
7. **Thyrotoxicosis**.
8. **Idiopathic AF**: in elderly patients (Lone AF). It is the most common sustained dysrhythmia present in 10 % of elderly patients > 60 years old.
9. **Paroxysmal AF**:
 - Due to - **Emotional stress**. - Increased **alcohol** intake.
 - **Vomiting**. - **Acute myocardial infarction**.

Treatment:

1. Treatment of the **cause**.
2. **Drugs**:
 - **Digitalis** (1st choice): 0.25-0.75 mg i.v. digoxin.
 - It slows A-V conduction causing a slow ventricular rate.
 - It converts flutter to AF or converts paroxysmal AF to sinus rhythm.
 - Rarely it converts flutter to normal sinus rhythm after stopping digitalis.
 - **Quinidine**
 - In atrial flutter it is the 2nd choice. It restores normal atrial depolarization.
 - In A.F., it must be given after patient's digitalization because it fastens AV conduction which increases the ventricular rate. It restores normal atrial depolarization.
 - **Verapamil** 75-150 μ g/Kg i.v over 1-3 min.
 - **β blockers** to control the ventricular rate in patients receiving digoxin preoperatively.
3. Anticoagulation in AF.
4. Synchronized DC cardioversion (2nd line in AF).
 - If - AF manifests for the 1st time during surgery.
 - Or - There is a fast ventricular rate and CO is decreased significantly.

B. Ventricular Dysrhythmias**1. Premature Ventricular Contractions (PVCs):**

ECG: **Premature** i.e. it occurs earlier than expected.

QRS complex is wide, aberrant and bizarre in shape and it is ≥ 3 mm in width.

Features:

- **Frequency**: Number/min. It may be bigeminy or trigeminy.
- **Coupling interval**: is between the PVC and the preceding normal beat. It is usually fixed, but may be variable.

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- **Compensatory pause:** is between the PVC and the next normal beat. It is a fully compensatory pause i.e. interval between the normal QRS complex immediately before and immediately after the PVC is exactly twice the basic RR interval.
- **PVCs form:** is either;
 - Uniform PVCs are due to a unifocus which may occur in a healthy or organic heart lesion.
 - Multiform PVCs are due to either multifoci or a unifocus but, it indicates an organic heart lesion.
 - **R on T phenomenon (PVC on T):** It occurs when the PVC occurs at or near the T wave peak of the preceding normal beat. It may precipitate ventricular tachycardia or VF.

Causes: due to ectopic foci located below the A-V node.

1. **Idiopathic:** it can occur in normal persons at rest and disappear with exercise

2. **Physiologic:**

- Excessive coffee, tea and alcohol consumption.
- Increased sympathetic activity.

3. **Pathologic:**

- CVS diseases as - Myocardial ischemia or infarction.
 - Myocarditis.
 - Hypertension.
 - Mitral valve prolapse.
 - Mechanical irritation of the ventricle e.g. C.V.P. or pulmonary artery catheter.
- Hypoxemia, hypercarbia, and acidosis.
- Hypokalemia and hypomagnesemia.

4. **Drugs:** • Digitalis toxicity.

Treatment:

It is only treated if

* Frequent > 5/min.	* Bigemny or trigemny PVCs.
* Multi-focal.	* Runs of > 3.
* R on T phenomenon.	

As these characteristics are associated with increased risk of ventricular tachycardia or V.F. therefore;

1- Treatment of the cause.

2- Lignocaine (of choice).

Initial i.v. bolus 1-2 mg/kg followed by 1-4 mg/min (20-50 µg/Kg/min) i.v. infusion.

3- Procainamide: 100 mg iv over 5 min up to 2 gm.

N.B.; If PVCs are associated with a slow atrial rate (escape beat) so, increase the HR by anticholinergic drugs which will lead to disappearance of PVCs.

2. Ventricular Tachycardia (V.T.):

ECG: A run of 3 or more consecutive PVCs.

HR: 120-250 /min. It is either regular or irregular.

- QRS complex: is broad. If the HR is very rapid, **Sine wave appearance** is present which is called **ventricular flutter**. It usually progresses to VF.
- P wave: is dissociated from the QRS complex i.e. independent atrial activity.
- Fusion beats or capture beats are present.
- In some patients, hereditary prolonged QT interval is present.

N.B.; Accelerated idio-ventricular rhythm:

HR 50-100/min with wide QRS complexes, but no P waves.

Types:

- a. **V.T. with pulse:** There is usually **no** hemodynamic instability.
- b. **Pulseless V.T.:** There is usually **hemodynamic** instability. It is more common.

C/P: It is a grave dysrhythmia **always** associated with **hemodynamic instability**

Beside the C/P of the cause, there are;

- Cannon waves in the **jugular venous** pulse.
- Variable 1st heart sound.

Causes:

1. Acute myocardial infarction (**The most common cause**).
2. Myocarditis.
3. Cardiomyopathy.
4. Chronic ischemic heart **disease** (especially when associated with a ventricular aneurysm).

Treatment:

Patient **resuscitation (CPR)** is **initiated** as cardiac arrest.

.....see later **Cardiopulmonary** resuscitation.

3- Ventricular Fibrillation (V.F.):

ECG: • QRS complex is not visible.

- Irregular fibrillation **pattern** which is either coarse or fine.

There is no CO resulting in **circulatory collapse**.

Cause: Due to chaotic **asynchronous ventricular** contractions.

.....The same causes as **V.T.**

Treatment:

.....The same as **V.T.**

Perioperative Cardiac Dysrhythmias**I. Preoperative Dysrhythmias:**

- If present, it should be treated **preoperatively** (postpone surgery if necessary).
- AF is the most common so, it is **treated** by digoxin to control the ventricular rate intraoperatively.

II. Intraoperative Dysrhythmias:

Incidence: 12 % in patients **undergoing** anesthesia.

30 % in patients with **C.V.S.** diseases.

Factors Affecting Intraoperative Dysrhythmias:**1. Ventilation Abnormalities:**

- **Hypoxemia:** Initially, it causes **tachycardia**.
Later on, it causes **bradycardia**.
- **Hypercarbia** produces ventricular **extra-systoles**.

2- Catecholamines: They cause **ventricular** dysrhythmias.**• Endogenous:**

- Inadequate analgesia.
- Inadequate depth of **anesthesia**.
- Airway manipulation (**laryngoscopy**, tracheal intubation and suctioning).
- Hypoxia and hypercarbia.
- Hyperthyroidism.
- Pheochromocytoma.

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● **Exogenous:**

- Sympathomimetics as adrenaline, or ephedrine.
- Adrenaline containing local anesthetic preparations especially with halothane and hypercarbia. (see maximal adrenaline dose).

N.B.; Enflurane is less likely to sensitize the myocardium while isoflurane does not sensitize the myocardium to adrenaline.

3- Electrolyte Disturbances:

● **Hypokalemia** causes ventricular dysrhythmias because it increases ventricular irritability especially in:

- Ischemic heart diseases.
- Patients receiving digoxin.
- Hyperventilation which causes hypocapnia. This results in respiratory alkalosis which causes K^+ shift into cells producing more hypokalemia (s. K^+ decreases by 0.5 mmol/L for every 1.3 Kpa "10 mm Hg" decrease in CO_2 tension).

● **Hyperkalemia** causes an atrio-ventricular conduction block up to cardiac arrest especially in: - Patients with renal impairment.

- The usage of suxamethonium in patients with burns, denervating injuries, paraplegia, or myopathies as it shifts K^+ out from muscle cells.

4. Malignant Hyperthermia:

- The most consistent early sign is unexplained and progressive tachycardia, then ventricular dysrhythmias occur.

5. Surgical Causes: especially with light anesthesia.

- Eye surgery (oculo-cardiac reflex) especially squint surgery.
- Anal stretch.
- Mesenteric traction.

These three causes increase vagal tone producing bradyarrhythmias.

- Pharyngeal or laryngeal surgery.
- Dental surgery (partially blocked by L.A. infiltrations).

Both cause tachyarrhythmias.

- Direct cardiac stimulation: as chest surgery or right heart catheterization with a PA catheter usually cause PVCs.

N.B.; Reflex Dysrhythmias:

- It occurs during light anesthesia due to sympathetic or parasympathetic stimulation.
- It includes all the surgical causes except direct cardiac stimulation.
- It is prevented by deepening the anesthesia.

6. Cardiac Diseases:

- Already existing dysrhythmias.
- Congestive heart failure.
- Ischemic heart diseases.
- Valvular heart disease.
- Myocarditis.
- Cardiomyopathy.

7. Drugs:

- Anesthetic drugs: (especially with hypercarbia) as halothane, and enflurane especially junctional rhythm.
- Ketamine blocks the reuptake of catecholamines.
- Muscle relaxants: * Suxamethonium causes bradycardia on repeated doses.
* Non-depolarizing muscle relaxants as pancuronium cause a vagolytic effect.
- Sympathomimetic drugs: as adrenaline and ephedrine.
- Methyl-xanthines: as aminophylline.
- Tricyclic antidepressants.
- Phenothiazines.
- MAO inhibitors.
- Digoxin: especially hypokalemic patients or those with renal impairment.

Management:

- Continuous intraoperative ECG monitoring is mandatory especially lead II.
- Hemodynamic status should be assessed.
- Correct the predisposing factors first. It may be the only treatment.
- Active treatment as anti-arrhythmics or cardioversion are indicated if;
 - o The dysrhythmias predispose to ventricular tachycardia or V.F.
 - o The dysrhythmias cause significant hemodynamic effects.
 - o The dysrhythmias are associated with myocardial ischemia.
- Types and treatmentsee above.

III. Postoperative dysrhythmias:**Causes:**

- Residual anesthetic agents especially halothane.
- Hypoxemia.
- Hypercarbia.
- Electrolyte or acid-base disturbances.
- Myocardial ischemia or infarction.
- Postoperative pain.
- Vagal stimulation e.g. by E.T.T. or a suction catheter.

Heart Block**Causes:****1. Organic Diseases:**

1- Diseases affecting the **conductive tissues** especially;

- Lenegre's disease: **sclerodegenerative changes** of the terminal portions of the bundle of His.
- Lev's disease: **Fibrous enchroachment** of the proximal portion of the bundle of His.

2- Diseases affecting the **cardiac tissue**;

- Myocardial ischemia or acute infarction.
- Myocarditis.
- Cardiomyopathies.
- Ventricular hypertrophy due to;
 - Valvular heart diseases.
 - AS, AI causing RBBB, LBBB.
 - Pulmonary hypertension causing RBBB.
 - Systemic hypertension causing LBBB.

1. Surgically produced (**iatrogenic**).

2. **Congenital** heart diseases.

2. Functional Disturbances:

1- Increased **vagal tone**.

2- **Drugs:**

Digitalis	Quinidine	Procainamide
Propranolol	Verapamil	Hyperkalemia

3. It may occur in **normal patients**, but rare.

Classification:**1. 1st Degree Heart Block:**

- ECG: prolonged PR interval > 0.2 seconds.

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- The condition is asymptomatic, only diagnosed by ECG.
- Treatment: No treatment is needed before anesthesia.

2. 2nd Degree Heart Block:

Some atrial impulses fail to reach the ventricle producing dropped beats.

a) Mobitz Type I (Wenckebach's Phenomena):

- ECG: Gradual progressive prolongation of the successive PR intervals followed by a dropped beat i.e. a P wave is not followed by a QRS complex.

b) Mobitz Type II:

- ECG:
 - PR interval is constant.
 - Some of the P waves are not conducted i.e. number of P waves are $>$ QRS complexes.
 - When atrial and ventricular contractions are in a ratio of 2:1 or 3:1, the pulse is slow and regular. When atrial and ventricular contractions are in more complex ratios as 3:2 or 4:3, the pulse is irregular with dropped beats.
- It is more serious than Mobitz type I because it frequently progresses to complete AV heart block.
- Treatment:

Preoperative insertion of artificial cardiac pacemaker is justified even in the absence of symptoms.

3. Left Bundle Branch Block (LBBB):**a) Complete LBBB:**

- ECG:
 - QRS width is ≥ 4 mm (i.e. complete) (normal QRS width ≤ 2.5 mm).
 - V_1 shows wide (\pm notched) -ve QS (\pm small r).
 - V_6 shows wide (\pm notched) +ve R (no small q).
 - T wave inversion in left chest leads (a 2ry change). If T wave inversion occurs in right chest leads, this is a 1ry change e.g. ischemia.
 - It decreases ECG evidence of myocardial infarction.
- Cause: Due to failure of conduction via the left bundle branch (as above).
- Treatment: It usually needs a pacemaker.

N.B.; ECG of the pacemaker pattern.

LBBB + a Pacemaker spike before the QRS complex.

b) Incomplete LBBB (Uni-fascicular Block):**1. Left Anterior (Fascicular) Hemi-block:**

- ECG:
 - As above with LBBB except QRS width is 2.5 – 4 mm (i.e. incomplete).
 - + • QRS axis is $\geq -45^\circ$ i.e. left axis deviation (the S wave in aVF equals or exceeds the R wave in L_1).
- Treatment: No treatment if it is isolated.

2. Left Posterior (Fascicular) Hemi-block:

- ECG:
 - As above with LBBB except QRS width is 2.5 – 4 mm (i.e. incomplete).
 - + • QRS axis is $\geq +120^\circ$ i.e. right axis deviation.
- Treatment: No treatment if it is isolated.

4. Right Bundle Branch Block (RBBB):

- ECG:
 - V_1 shows rSR' complex with a wide R'.
 - V_6 shows qRS complex.
 - T wave inversion in right chest leads (a 2ry change). If T wave inversion occurs in left chest leads, this is a 1ry change e.g. ischemia.
- Treatment: No treatment if it is isolated.

5. Bi-Fascicular Block:

It is RBBB + left anterior or left posterior hemi-block.

- ECG: • RBBB + left anterior hemiblock appears as RBBB + left axis deviation.
- RBBB + left posterior hemiblock appears as RBBB + right axis deviation.

- Clinically:

Asymptomatic patients very rarely progress to complete heart block before anesthesia, so implantation of a permanent or temporary pacemaker is unnecessary but an external pacemaker should be available in the operating room.

6. 3rd Degree Heart Block (Complete Heart Block):

(Complete A-V Block) (Tri-Fasicular block):

- Cause: All impulses from the atria are not conducted to the ventricles therefore, no relationship between atrial and ventricular contractions is present.
It is either acquired or congenital.
- ECG: • No relation between P waves and QRS complexes is present, where the atrial rate is regular and faster than the ventricular rate which is also regular.
- The PR interval is completely variable.
- It is of 2 types;
 - Complete AV nodal block: QRS complexes are normal in shape.
HR is 45 – 55 / min and regular.
 - Complete infranodal block: QRS complexes are wide.
HR is 30-40/min and regular.
HR does not vary with exercise.
- It is either continuous or intermittent.
- Clinically:
 - Venous cannon waves may be present.
 - Adam-Stokes attacks:
 - They are episodes of ventricular asystole.
 - They are characterized by light headedness, dizziness, rapid loss of consciousness, and convulsions (in contrast to epilepsy, there is rapid recovery once the heart starts to beat again).
 - CHF: may occur if the SV is unable to offset the decreased CO produced by the severe bradycardia of the AV block.
- Treatment:
 - 1- A permanent artificial cardiac pacemaker is mandatory (unless congenital).
 - 2- Before general anesthesia, a temporary pacemaker should be inserted.
 - 3- In an emergency, **isoprenaline i.v. infusion 0.5-8 µg/min** (according to the response) may maintain an adequate ventricular rate (**pharmacologic pacemaker**) until a pacemaker is inserted.

Avoid antiarrhythmic drugs in the absence of the pacemaker.

Anesthetic Management of Patients with Heart Block

Preoperative Management:

- 1- Determine the type (by ECG) and symptoms as CHF or syncopal attacks.
- 2- **Avoid drugs** that slow AV conduction as β blockers, digoxin, or verapamil and use drugs that fasten AV conduction as isoprenaline, or atropine.
- 3- Indications of a **temporary or permanent pacemaker**
.....See later "Pacemakers".

Intraoperative Management:

Monitoring: Standard..... Especially ECG.

A **standby pacemaker** should be available.

Care is taken to **avoid blood loss and or hypotension** and also **with using vasodilators** because the HR is unable to be increased.

ANESTHESIA WITH CARDIOVASCULAR DISEASES**Postoperative Management:**

A decision whether a permanent pacemaker is needed or not should be made by a cardiologist after the immediate postoperative period.

Anesthetic Management of Patients with Pacemakers

.....See later.

Cardioversion (DC shock, Defibrillator)**Indication:**

- **Re-entrant tachyarrhythmias** which;

- Produce hemodynamic instability or ischemia.
- Do not respond to other measures.

E.g. - Ventricular tachycardia.

- Ventricular fibrillation.
- Paroxysmal supraventricular tachycardia.
- Atrial flutter.
- Atrial fibrillation especially.
 - Symptomatic AF < 12 month's duration.
 - A history of embolism.
 - Recent onset AF.
 - No response to medical treatment.

N.B.; **Cardioversion is not effective for**

- Arrhythmias produced from enhanced automaticity (**Multi-focal atrial tachycardia**).
- Triggered activity (**digitalis induced arrhythmias**).

As cardioversion can even trigger, more serious ventricular arrhythmias.

- Cardioversion is either;

- Elective cardioversion for chronic arrhythmias. or
- Emergency cardioversion for life threatening arrhythmias.

Mechanism of Action:

DC electrical discharge will pass via the heart causing;

- Simultaneous depolarization of all excitable myocardial cells.
- Interruption of abnormal pathways and foci.
- Prolongation of the refractory period.

Technique:

- After **heavy sedation or light general anesthesia**, a DC shock is applied by either self adhesive pads or reusable paddles.

- **Paddles' sizes** are 8-13 cm which is the adult size.

8 cm which is the child size.

4.5 cm which is the infant size.

- **Larger paddles are preferred** to decrease any shock-induced myocardial necrosis by distributing the current over a wide area.

- **Placement of paddles** is either;

a. Antero-laterally with the patient in the supine position (standard):

- One paddle is placed on the right 2nd intercostal space next to the sternum.
- The other is placed on the left 5th intercostal space in the mid-clavicular line (i.e. **sternum and apex**).

b. Antero-posteriorly with the patient in the lateral position.

- One paddle is placed on the left 5th intercostal space in the mid-clavicular line (**apex**).
- The other paddle is placed posteriorly in the **left infra-scapular region**.

The paddles should not be placed over bones (scapula, sternum or vertebrae) or within 12 cm of a permanent pacemaker.

- The **skin** must be protected with electrolyte jelly, saline-soaked gauze or any type of conducting pads to - Prevent skin burn.
- Decrease trans-thoracic impedance.

- Synchronization:

- It is the timing of the delivery of the shock during the QRS complex **away from the T wave or ST segment** i.e. the synchronized DC shock is like the unsynchronized DC shock, if it is applied on a T wave, it may precipitate VF.
- A synchronized DC shock is needed in all tachyarrhythmias (as PSVT, atrial flutter, AF, or VT with pulse).
- An unsynchronized DC shock is needed in VF or VT without pulse.

- Energy required:

The energy output should be kept to the minimal effective level to prevent myocardial damage so, start with the minimum energy.

Arrhythmias	Adult (Joules)	Child (Joules/Kg)
• Paroxysmal SVT.	25-50	0.5-1 J/Kg
• Hemodynamically stable VT.	25-50	0.5-1 J/Kg
• AF.	50-100	1-1.5 J/Kg
• Hemodynamically unstable VT.	200-400	2 J/Kg
• VF.	200-400	2 J/Kg

Regardless of the type of arrhythmias, a higher energy level is required when the 1st shock is ineffective.

So, gradually increase the energy with 50-100 Joules increments as needed.

N.B.; Higher energy levels may be needed in a patient with a thickened thorax e.g. emphysema.

Precautions:

- If **ventricular arrhythmias** develop following the initial shock, lidocaine should be given before the next one.
- If the patient remains in VF after 3 attempts of DC shock, **CPR** should be continued and the shocks should be repeated after i.v. epinephrine.
- **Asystole** does not respond to DC shock so, it should be distinguished from VF by multiple ECG leads.

- The place for performance of cardioversion in elective cases:

Only in areas where a **full range of cardiopulmonary resuscitations** including drugs, cardiac pacing capabilities and airway management are available e.g. ICU, emergency room, or recovery room.

Anesthetic Management in elective cases

Preanesthetic Management:

Patient Preparation:

1. **Assess and manage pre-existing diseases** e.g. rheumatic diseases, arterio-sclerotic heart diseases, myocardial infarction, CHF, or cerebro-vascular occlusive diseases.

2. Patients should **fast for 6-8 hours** before the procedure.

3. **Drugs:**

- **Digitalis** therapy predisposes to post-cardioversion arrhythmias.

So, in some centers, it is withheld for at least 24 hours before cardioversion, but in other centers, withholding digitalis is not necessary as long as no evidence of the toxicity occurs.

- **Quinidine** therapy is often started in patients with AF 1-2 days before the procedure to help maintain the normal sinus rhythm.

- **Anticoagulant** therapy with warfarin is needed in high risk patients as:

- MS with AF.
- Prosthetic mitral valve.

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- History of embolic phenomenon.
- CHF.
- Arrhythmias for > 48 hours.

The patient should receive prophylactic anticoagulants 1-2 weeks before the procedure because cardioversion can induce systemic embolization.

4- Preoperative Investigations:

Routine.....+

- Electrolyte and acid-base abnormalities should be corrected as they may contribute to the arrhythmias and their recurrence.
- A 12 lead ECG is performed
 - o Immediately before the procedure to confirm that the arrhythmia is still present.
 - o Immediately after the procedure to detect any new arrhythmia.

5. Premedications:

- * Sedation is needed to decrease the circulatory endogenous catecholamines concentration.
- * Atropine is avoided.

6. The place for performance of cardioversion is as above.....

Intra-anesthetic Management:**Monitoring:**

- The minimum monitoring consists of an ECG, ABP, and pulse oximetry.
- Monitor the level of consciousness, best by maintaining continuous verbal contact with the patient.

Choice of Anesthesia:

Heavy sedation or light general anesthesia are used.

Preoxygenation with 100 % O₂ for 1-2 minutes is advised.

Induction:

- Short acting agents as methohexitol, propofol, etomidate or benzodiazepines (midazolam, diazepam) in small increments every 2-3 min (if necessary) are used to maintain C.V.S. stability.
- When the patient is insensible i.e. loss of verbal contact with the patient or loss of eyelid reflex (used by some anesthetists)
 - Secure the airway and give O₂ by a suitable breathing system.
 - Apply the shock which usually arouses the patient.

If repeated shocks are required,

- Incremental doses of anesthetics may be given.
- Transient airway obstruction or apnea may occur.

Post-anesthetic Management:

- Continue monitoring of patients during immediate postoperative period for

- Recurrence of arrhythmias.
- Complications.

- Complications of cardioversion:

1. Transient myocardial depression.
2. Post-shock arrhythmias e.g. VF.

They may occur even with proper synchronization especially if there is one of the following;

- Hypokalemia.
- Ischemia.
- Digitalis toxicity.
- QT prolongation caused by as before.....

3. Arterial (systemic) embolization especially in high risk patients... ..see above.

Cardiac Pacemakers

Definition:

It is a device which can artificially pace the heart electronically so; the myocardium will contract when stimulated.

It was invented in the 1950s.

Pacemaker Identification

In 1970s, the **Intersociety commission of Heart Disease (ICHD)** suggested a classification code for cardiac pacemakers, which is now widely accepted.

The original nomenclature involved a 3-letter identification code:

The 1st letter of the code, signifies the chamber(s) paced.

The 2nd letter of the code, signifies the chamber(s) sensed

The 3rd letter of the code, signifies the mode of response to a sensed P or R wave, either inhibited or triggered.

Examples:

VOO pacemaker: - It paces the ventricle (ventricular pacemaker).

- It has no sensing capability (it does not sense intrinsic R waves or P waves).
- It has no mode i.e. **asynchronous (fixed rate)**.

VVI pacemaker: - It paces the ventricle (ventricular pacemaker).

- It senses the ventricle (i.e. it senses intrinsic R waves).
- It is inhibited (i.e. when it senses intrinsic R wave, it inhibits the artificial pacing).

It is the **standard ventricular demand pacemaker**.

DVI pacemaker: - It paces both the atrium and ventricle.

- It senses the R wave of the ventricle.
- It is inhibited (i.e.....).

DDD pacemaker: - It paces both the atrium and ventricles.

- It senses both R waves of the ventricle and P waves of the atrium.
- It is triggered when it senses the P wave of atrial activity, then it is inhibited when it senses the R wave of ventricular activity after the preset atrio-ventricular interval i.e. **synchronized**.

Indications of Pacemakers:

Indications of Temporary Pacemakers:

(1) Bradyarrhythmias and Heart Block:

a. Severe Sinus Bradycardia:

E.g.: - After myocardial infarction or after open cardiac surgery.

- During instances of profuse vagotonia.
- Overdoses of drugs affecting the conduction system, such as cholinergic agents, Ca^{++} channel blockers, β adrenergic blockers, and digoxin.

b. Other Bradyarrhythmias:

- AF with slow ventricular response.
- Bradyarrhythmias after cardioversion.
- Patients who are pacemaker-dependent with pacemaker dysfunction.

c. 2nd Degree Heart Block:

- Mobitz type I: It is often transient and rarely necessitates pacing. Nowadays it has been recognized that there is an increased mortality, if it is not paced.

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- Mobitz type II:

- It usually indicates destruction of the conduction system at the level of or below the bundle of His and it usually progresses to a complete AV block.
- Temporary pacing is indicated: - before general anesthesia.
and - for acute management.

with subsequent implantation of a permanent pacemaker.

N.B.:- 1st degree heart block does not need a pacemaker.

d. LBBB:

- Complete LBBB: requirement of a pacemaker is according to the patient's condition.
- Incomplete (uni-fascicular) LBBB: it does not need a pacemaker, if it is isolated.

e. RBBB:

- It does not need a pacemaker if it is isolated.

f. Bi-fascicular Block:

- A pacemaker is indicated only if it is symptomatic as it may progress to CHB.
- Asymptomatic patients, usually do not need a pacemaker, but an external pacemaker should be available in the operating room.

g. Complete Heart Block (CHB):

- Temporary pacing is indicated before general anesthesia to maintain ABP and prevent ventricular escape beats.

(2) Tachyarrhythmias:

Hemodynamically disabling tachyarrhythmias with;

- Resistance or intolerance to drug therapy in conditions when cardioversion is relatively contraindicated such as (e.g. digoxin therapy).
- Resistance to cardioversion.

(3) Prophylactic Pacing:

- In acute myocardial infarction complicated by various combinations of heart block:
- RBBB + left anterior hemiblock (which is most common in the acute phase of anterior MI).
- RBBB + left posterior hemiblock.
- LBBB with or without 1st degree AV block.
- Mobitz type I or type II 2nd degree block.
- Prophylactic pacing is rarely necessary in acute inferior wall myocardial infarction.

Indications of a Permanent (Implanted) Pacemaker:

It is mainly for symptomatic bradyarrhythmias.

A- SA nodal diseases: **Sick sinus syndrome:**

is the most common indication, it usually occurs in elderly patients.

B- AV nodal diseases:

1. 2nd degree heart block: - Mobitz type I: Increased mortality is now recognized if not paced.
- Mobitz type II: as it usually progresses to complete heart block.
2. Bi-fascicular block: - Only if symptomatic.
3. Complete heart block: - Except if congenital.
4. Post-myocardial infarction:- If any of the above indications exists.

Types of The Pacemakers:

1. Transvenous pacing (endocardial lead).
2. External transcutaneous pacing.

3. Transesophageal pacing.
4. Transthoracic pacing (subcostal, epicardial or myocardial lead).

Anesthetic Management of a Patient with a Permanent Pacemaker

Undergoing Surgery:

Preoperative Management:

Preoperative Evaluation:

1. Patient evaluation for;
 - The presence of **coexisting diseases**.
 - **Pacemaker evaluation** for the function.
 - **Cause of the insertion** of the pacemaker.
 - **Date of the insertion** of the pacemaker and **the last test date**.
 - **Type of the pacemaker** (programmable or not).
2. Ask for **anticoagulation**:

Because patients with congestive heart failure and a cardiac pacemaker may receive anticoagulant therapy. So, **caution** must be taken when using **regional anesthesia**.

3. Preoperative investigations:

a. ECG (12 leads):

The pacemaker rate detected by the pacemaker spikes.

b. Chest X-ray film: should be checked for lead position or lead fracture.

c. Other routine laboratory investigations:

- * CBC.
- * Arterial blood gases.
- * Coagulation profile.
- * Renal function profile.
- * Blood sugar.
- * Liver function profile.
- * Serum electrolytes especially s. K^+ .
- * Urine analysis.
- * Serum digoxin and antiarrhythmic drugs level.

Preoperative Patient Preparation:

1. **Preoperative correction of s. K^+** .
2. **Prepare equipment and drugs for CPR** in case of pacemaker failure.
As: - Atropine and isoprenaline to treat bradycardia and heart block.
- Lignocaine and DC shock to treat ventricular arrhythmias.
3. Changing the mode of the pacemaker to be **fixed mode**. This can be achieved by application of a **magnet** over the generator of some types of the pacemakers.

Intraoperative Management:

Monitoring:

1. ECG monitor: should be continuously monitored.
2. Pulse oximetry.
3. NIBP monitor.
4. ET CO_2 monitor.
- + 5. Precordial or esophageal stethoscope.
6. Esophageal or rectal temperature probe.
7. Transesophageal echocardiography.
8. Invasive arterial BP monitor.
9. CVP.
10. PA catheter.

ANESTHESIA WITH CARDIOVASCULAR DISEASES**Anesthetic Techniques (Choice of Anesthesia):****A. Regional Anesthesia:**

- It can be used without interfering with the pacemaker function.

B. General Anesthesia:**Induction:**

- IV agents will **not** affect the pacing threshold.

Succinylcholine:

- It causes fasciculations which can inhibit unipolar pacemakers (myopotentials interference) because it is detected by the pacemaker as patient's pulse, so;
 1. Avoid use of succinylcholine.
 2. Make defasciculation by nondepolarizing muscle relaxants.
- Clinically, succinylcholine is generally used safely.

Maintenance:

- Opioids and inhalational anesthetics will **not** affect the pacing threshold.

Intraoperative Complications:

1. Intraoperative Use of Defibrillators e.g.: For VF, take care of the following:

- * The paddles should **not** be placed directly over the pulse generator.
- * They may cause endocardial burns and fibrosis at the electrode-endocardial interface.

2. Electro-Magnetic Interference (EMI):**a. Electrocautery:**

- It causes **pacemaker failure** because the electrical artifact is sensed as an intrinsic patient's heart rate by the pacemaker.

Asynchronous fixed rate pacemakers (VOO or AOO) are **not affected by electrocautery.**

- Precautions with cautery:

1. Use a bipolar electrocautery forceps.
2. Use electrocautery in **short bursts**.
3. Set the electrocautery **current at the lowest functional level**.
4. The **ground plate** should be placed as close to the operative site as possible and as **far from the pacemaker generator** as possible (never have the generator between the ground plate and the pacing electrode).
5. The electrocautery **should not be used within 15 cm of the generator**.
6. Change the **pacemaker mode to asynchronous** by a **high-powered magnet**.
7. If intraoperative pacemaker failure occurs;
 - **Emergency transcutaneous pacemaker** (physio-control Quick pace).
 - And • **Isoprenaline infusion**.
 - Should be readily available.
8. **CPR measures (equipment and drugs)** should be readily available.

N.B.: Magnetic Resonant Imaging (MRI):

- It is **absolutely contraindicated** by most generator manufacturers as deaths have been reported because it causes pacing inhibition or rapid pacing.
- If MRI is absolutely indicated, the pacemaker should be programmed to its lowest voltage output or pulse width or to OOO mode (provided that the patient has an adequate underlying rhythm).

Postoperative Management:

In the ICU special care to:

1. **Pacemaker function** which should be reevaluated.
2. Avoid **postoperative shivering** as it may cause myopotentials which are misinterpreted by the pacemaker as intrinsic patient's heart rate causing inhibition of the pacemaker.

Q: Anesthesia outside the operation room (Offsite anesthesia), discuss?

Q: Anesthesia in austere conditions, discuss?

A: Discuss 1- Hyperbaric chamber anesthesia.

2- ECT anesthesia.

3- Radio-diagnosis (MRI and CT) anesthesia.

4- Radio-therapy anesthesia.

5- Anesthesia for ESWL.

6- Anesthesia for ERCP.

7- Anesthesia for interventional neuro-radiology.

8- Office based anesthesia and dental anesthesia.

9- Cardiac indications as pacemaker insertion

10- Mass casualty anesthesia.

+ **Discuss** • The type of patients (pre-, intra- and postoperative).

• Indication of each.

• Light general and local anesthesia + conscious sedation.

• Postoperative management

Myocardial Stunning and Hibernation

There are 3 outcomes after myocardial ischemia (i.e. depressed flow and depressed function) which are;

1- Myocardial Stunning.

2- Myocardial Hibernation.

3- Myocardial Infarction.

Myocardial infarction: It is irreversible with severe lethal cellular injury, both the flow and function are depressed (i.e. flow-function matching).

Ischemia

There is - Loss of function.

- Decreased coronary flow.

- Hypoxia.

- Viable cells.



	Stunning	Hibernation	Infarction
Function	Lost	Lost	Lost
Coronary flow	Normal	Chronic (not a severe) decrease	Decrease
Hypoxia	Absent	Absent	Present
Cell viability	Viable	Viable	Not viable

Myocardial Stunning	Myocardial Hibernation
Definition: - It is a transient fully reversible LV dysfunction (detected by segmental wall motion abnormalities) that persists after reperfusion (for hours to days) i.e. delayed recovery with; • Absence of irreversible damage (mild sub-lethal cellular injury).	It was first described in 1985 by Rahimtoola. Definition: - It is a chronic transient fully or partially reversible LV dysfunction (detected by segmental wall motion abnormalities) that occurs after prolonged (not severe) myocardial hypoperfusion with; • Viable myocardium (myocytes), but

ANESTHESIA WITH CARDIOVASCULAR DISEASES

<ul style="list-style-type: none"> • Restoration of normal or near-normal coronary flow (abnormal function with normal or near normal flow). i.e. flow-function mismatch or uncoupling. 	<ul style="list-style-type: none"> with reduced contractility. - It is partially or fully reversed to normal after either; • Restoration of coronary flow (in cases of ischemic heart diseases). • Reduction of O₂ demand (in cases of chronic LV overload). - Both flow and function are reduced i.e. flow- function match or coupling).
---	--

N.B.; Reperfusion Injury:

- Although ischemic myocardium can only be salvaged by reperfusion, reperfusion itself can lead to additional cellular injury that further augments the ischemic state of injury.

- Causes:

a- **During the initial phase of reperfusion;** injury is mainly caused by the consequences of ischemic **calcium overload** together with the re-supply of energy that triggers several critical intra-cellular events including **activation of cellular enzymes and over-activation of the contractile apparatus.**

b- **Later during the time course of reperfusion;** injury is further augmented by leukocytes that become **activated and release a variety of mediators** including O₂ derived free radicals.

- Reperfusion injury may cause cell death and infarction (lethal reperfusion injury). The flow is preserved, but the function is reduced (i.e. flow-function mismatch).

- **Cardio-protection of inhalational agents as halothane** (1 MAC for the first 15 min of reperfusion after coronary occlusion), **enflurane, sevoflurane, and desflurane** is apparent during reperfusion. The mechanism of this protection includes;

- These volatile agents interact with the sarcoplasmic reticulum ryanodine receptors of perfused heart cells.

- They also reduce secondary reperfusion injury caused by activated leukocytes.

Surprisingly, **no cardio-protective effect against lethal reperfusion injury** was found for isoflurane both in vitro and in vivo.

CHAPTER 10

ANESTHESIA WITH/FOR

CONGENITAL HEART

DISEASES (CHD)

Incidence: 1% of all live births.

Classification:

I. Obstructive Lesions: → CHF.

- a. Left ventricle:
 1. Congenital Aortic Stenosis.
 2. Coarctation of the Aorta.
 3. Interrupted Aortic Arch Anomaly.
- b. Right ventricle:
 4. Pulmonary Atresia → ↓ Pulmonary blood flow symptoms.

II. Left to Right Intra-Cardiac Shunt (Simple Shunts): → ↑ pulmonary blood flow.

1. Secundum Atrial Septal Defect (ASD). symptoms.
2. Primum Atrial Septal Defect (ASD) = Endocardial Cushion Defect.
3. Ventricular Septal Defect (VSD).
4. Patent Ductus Arteriosus (PDA).
5. Partial Anomalous Pulmonary Venous Return (considered as a group V).

III. Right to Left Intra-Cardiac Shunt: → ↓ pulmonary blood flow symptoms.

1. Tetralogy of Fallot.
2. Ebstein's Malformation of Tricuspid Valve.
3. Tricuspid Atresia.
4. Patent Foramen Ovale.

IV. Separation of the Pulmonary & Systemic Circulation: → ↑ pulmonary blood flow symptoms.

1. Transposition of the Great Vessels.

V. Mixing of the Pulmonary & Systemic Circulation: → ↑ or ↓ pulmonary blood flow.

1. Truncus Arteriosus.
2. Partial Anomalous Pulmonary Venous Return.
3. Total Anomalous Pulmonary Venous Return.
4. Hypoplastic Left Heart Syndrome.
5. Double Outlet Right Ventricle.
6. Single Ventricle or Single Atrium.

VI. Mechanical Obstruction of the Trachea:

1. Double Aortic Arch.
2. Aberrant Left Pulmonary Artery.
3. Absent Pulmonary Valve.

Anesthetic Management

Patients are one of the following groups;

- a) Patients who have undergone corrective cardiac surgery. These are considered normal, but a prophylactic antibiotic is essential.
- b) Patients who had only palliative surgery.
- c) Patients who have not yet undergone any cardiac surgery.

ANESTHESIA WITH/FOR CONGENITAL HEART DISEASES

d) Patients who have inoperable conditions and may be awaiting cardiac transplantation. b, c, and d need special anesthetic management according to the disease.

Q: What are the causes of the cyanotic heart diseases in the 1st year of life (or at birth)?

A: Groups III, IV, V, and Ib.

Preoperative Management:**A. Detection of Congenital Heart Disease:**

C/P: Many are asymptomatic up to adult age but others show;

1- Failure to gain weight in infancy or slow physical development in children and easily fatigability.

2- Symptoms of increased pulmonary blood flow as pulmonary congestion which causes;

- Recurrent chest infection.

- Later on pulmonary hypertension occurs.

- Finally congestive heart failure (CHF) occurs with exertional dyspnea, cyanosis, syncope, and anginal attacks.

3- Symptoms of decreased pulmonary blood flow as pulmonary oligemia which causes arterial hypoxemia.

- Cyanosis, tachypnea especially on feeding.

4- Heart murmurs.

Investigations:

1. Echocardiography: is the initial diagnosis. It is done if;

- * Congenital heart disease is suspected by the above C/P.

- * Associated congenital anomalies.

2. Doppler U/S.

3. Computed Tomography (CT).

4. Magnetic Resonance Images (MRI).

5. Cardiac Catheterization and Selective Angio-cardiography: They are the most definitive diagnostic techniques available.

6. ECG:

It shows: * Ventricular or atrial enlargement.

- * Associated arrhythmias (very rare).

7. Chest X-ray:

It shows: - Pulmonary congestion, if pulmonary blood flow is increased.

- Pulmonary oligemia, if pulmonary blood flow is decreased.

- Chamber enlargement.

- Characteristic shape as boot-shaped heart of F4.

B. Detection of General Complications and Problems: in all congenital heart disease

1. Infective Endocarditis: Patients should receive prophylactic antibiotics before any dental or surgical procedure.

2. Hyper-uricemia (increased uric acid): Due to increased urate reabsorption 2ry to renal hypoperfusion. It may progress to renal impairment.

Monitoring: Standard + Invasive BP.

Left to Right Intra-Cardiac Shunt (Simple Shunts):**Pathophysiology:** (in all)

- Simple shunts are isolated abnormal communications between the right and left sides of the heart so, blood flows across from the left to the right side. This increases blood flow through the right heart leading to increasing the pulmonary blood flow. This is because the pressures are normally higher on the left side.

- **The ratio of pulmonary to systemic blood flow** can be calculated from oxygen saturations at the time of catheterization by the following equation:

$$Q_p \times C_{pv}O_2 - C_{pa}O_2 = Q_s \times C_aO_2 - C_{\bar{v}}O_2$$

$$\frac{Q_p}{Q_s} = \frac{C_aO_2 - C_{\bar{v}}O_2}{C_{pv}O_2 - C_{pa}O_2}$$

C_aO_2 = O_2 content in systemic arterial blood

$C_{pa}O_2 = C_{\bar{v}}O_2$ = O_2 content in pulmonary arterial blood or = O_2 content in mixed venous blood.

$C_{pv}O_2 = C_{\bar{c}}O_2$ = O_2 content in pulmonary venous blood or = O_2 content in end pulmonary capillary blood.

Q_p = Pulmonary blood flow/min

Q_s = Systemic blood flow/min

A ratio > 1 indicates a left to right shunt.

A ratio < 1 indicates a right to left shunt.

A ratio = 1 indicates either: - No shunt.

Or - Bidirectional shunt of opposing magnitudes.

Sequences:

• **Increased pulmonary blood flow** causes **pulmonary vascular congestion** which in turn increases **extra-vascular lung water**. This interferes with gas exchange, decreases lung compliance, and increases the work of breathing.

• Over the course of **several years**, the chronic increase in pulmonary blood flow causes **irreversible vascular changes** which cause an **irreversible increase in pulmonary vascular resistance**. The later increases RV afterload and causes **RV hypertrophy** with a progressive increase in RV pressure. With advanced disease, the **pressure within the right heart can exceed** that within the left heart resulting in **reversal of the shunt** i.e. it becomes right to left (**Eisenmenger's Syndrome**).

Reversal of shunt **decreases pulmonary blood flow** and increases arterial hypoxemia so, **cyanosis occurs**. It contraindicates surgical correction of congenital heart disease.

Simple shunts include:

	Secundum ASD	Primum ASD (Endocardial Cushion Defect)	VSD	PDA (Patent Ductus Arteriosus)
Site of defect	- In the inter-atrial septum. - Vary from a single opening to a fenestrated septum.		- In the inter-ventricular septum. - Vary from a single opening to a fenestrated septum.	Located between the aorta (systemic circulation) and pulmonary artery (pulmonary circulation).
C/P	<ul style="list-style-type: none"> • Asymptomatic if small and symptoms can appear at adult age (2nd or 3rd decade of life). • There are symptoms of increased pulmonary blood flow. • Chest X-ray shows..... • There is systolic murmur, except in PDA, it is machinery murmur i.e. continuous systolic and diastolic. The murmur increases directly with the size of the opening. • Associated with other valve diseases as MR, TR, or AR. 			
Treatment	Surgical correction by 2 steps: a. Initially: palliative banding of PA to increase PVR and decrease the magnitude of the shunt. b. Later on, complete repair using cardiopulmonary bypass.			1- Surgical ligation . 2. Indomethacin Action: It closes PDA especially in premature infants with respiratory distress syndrome

ANESTHESIA WITH/FOR CONGENITAL HEART DISEASES

	- Heart block may occur after successful repair.	because it is a potent inhibitor of PG forming cyclo-oxygenase so, PGs synthesis is decreased causing closure of DA.
Anesthetic Management	<p>1. Avoid paradoxical embolism into the cerebral or coronary circulation, regardless of the direction of the blood flow so, meticulous exclusion of air bubbles or clots from i.v. fluids is required.</p> <p>2. Increase pulmonary vascular resistance: This decreases the shunt e.g., IPPV.</p> <p>3. Decrease systemic vascular resistance: This decreases the shunt e.g. volatile agents.</p> <p>4. When Eisenmenger's syndrome occursthe same anesthetic management of Fallot Tetralogy.</p> <p>N.B.; Eisenmenger's syndrome does not occur with PDA.</p>	

Q: Discuss the anesthetic management of congenital heart diseases in adult patients?

A: Adult patients may have one of the following diseases, either treated or not, ASD, VSD, PDA, Fallot Tetralogy, mitral valve prolapse, or coarctation of the aorta.

Q: Discuss the anesthetic management of adult onset congenital heart diseases?

A: They include; ASD, VSD, PDA, and mitral valve prolapse,

Right to Left Intra-Cardiac Shunt

Tetralogy of Fallot:

Incidence: 10% of all CHD

Pathology:

It consists of (figure 10-1):

- 1- **VSD:** Typically large, single and sub-aortic.
- 2- **Overriding of the aorta** on the pulmonary artery outflow tract:

The shunt has 2 components:

- a. **Fixed component:** It is determined by the severity of RV obstruction.
- b. **Variable component:** It is determined by SVR and PVR.

- 3- **RV outflow obstruction** i.e. obstruction of pulmonary artery tract by:

* Infundibular pulmonary artery stenosis mainly.

* Pulmonary stenosis in 20-25% of cases.

* The distal pulmonary artery may be hypo-plastic or even absent which decreased pulmonary blood flow.

- 4- **RV hypertrophy:**

Due to the large VSD which permits continuous exposure of the RV to high pressures of the LV. This makes the right ventricular pressure nearly as high the left ventricular pressure causing cardiomyopathy later on.

C/P:

- Symptoms usually start at **6 months of age**.

1. Symptoms of Decreased Pulmonary

Blood Flow:

Lung oligemia causes arterial hypoxemia which produces **cyanosis** (especially on closure of DA). This causes;

* **Clubbing** of the distal ends of the digits.

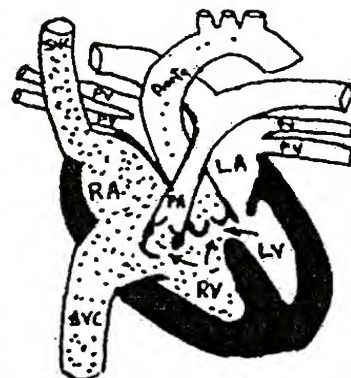


Figure 10-1; Tetralogy of Fallot

- * Arterial blood gases show **decreased PaO₂ < 50 mm Hg** even with 100% O₂ breathing.
- * **Squatting** increases SVR by kinking of the large arteries in the inguinal area which decreases the magnitude of the right to left shunt. This increases pulmonary blood flow which improves arterial oxygenation and CO₂ elimination.

2. Hyper-Cyanotic Attacks (or Tet Spells):

- The peak incidence is at the **1st 6 month of age** and decreases with advanced age.
- Mechanism: it is unknown, but a possible cause is sudden decrease in pulmonary blood flow due to;

- Spasm of the infundibular cardiac muscle due to sympathetic stimulation.

Or • Decreased SVR.

- Precipitating factors:

- It can occur spontaneously.

Or • After effort e.g. crying, exercise, feeding, or defecation.

C/P: There is hyperventilation with: - More arterial hypoxemia causing syncope.
- Increased arterial CO₂ causing metabolic acidosis.

Treatment:

- 1- β_2 antagonists as esmolol or propranolol to relieve infundibular spasm.
- 2- IV fluids and phenylephrine (to treat the decrease in SVR).
Avoid sympathomimetics with β_2 agonist e.g. ephedrine as they may cause spasm of the infundibulum.
- 3- Correction of metabolic acidosis by NaHCO₃.
- 4- Morphine which causes central decrease of the hyper-cyanotic response.

3. 2ry Polycythemia (Erythrocytosis):

- Due to chronic hypoxia in cyanotic heart diseases, enhancement of erythropoietin secretion from kidneys occurs to restore tissue oxygen concentration to normal.

- Sequelae:

a) Compensated Erythrocytosis:

Where Hct is stable and **less than 65%** allowing O₂ to return to normal.

b) Uncompensated Erythrocytosis:

- Where Hct is **more than 65-70%** i.e. hyper-viscosity of the blood.
- This interferes with O₂ delivery.
- Also, it increases the risk of thrombo-embolism especially in renal, pulmonary, and cerebral vessels (causing a **stroke**).
- A **brain abscess** may occur on top of the infarcted area producing an abrupt onset of headache, fever, lethargy, emesis, and seizures due to bacterial infection in the areas of previous cerebral infarctions.
- **Coagulation defects** due to
- Deficiency in the synthesis of vitamin K-dependent clotting factors in the liver.
- Deficiency in platelet aggregation.
- Treatment of uncompensated erythrocytosis: Phlebotomy.

4. Infective Endocarditis: Very common so,.....

6. Death: It occurs as follows: 25% die within the first year.

- 40% die within 4 years.
- 70% die within 10 years.
- 95% die within 40 years.

Investigations: As before.....

Treatment:

Surgical repair as the following;

ANESTHESIA WITH/FOR CONGENITAL HEART DISEASES

1) Initially:

a. Waterston shunt:

- Anastomosis between the ascending thoracic aorta and right pulmonary artery.

b. Blalock – Taussing shunt (the best)

- Anastomosis between a branch of the ascending thoracic aorta and one of the pulmonary arteries (e.g. end to side anastomosis between the left subclavian artery and the right pulmonary artery on the side opposite to aortic arch).

2) Later on, complete surgical repair is done.

- It is done at ages of 3-6 years by cardiopulmonary bypass.

Anesthetic Management: (opposite to the left to right shunt).

Aim:

(1) Avoid paradoxical embolism.....

(2) Decrease pulmonary vascular resistance. This decreases the shunt.

So, avoid factors that increase PVR as:

- Hypoxia so; increase inspired O₂ concentration.
- Hypercarbia so; maintain hypocarbia.
- Acidosis so; maintain alkalosis.
- Hypothermia so; maintain body temperature.
- PEEP or IPPV (increased airway pressure > 15 mm Hg), but clinically IPPV has minimal effects.
- Opening of the chest causes loss of -ve intra-pleural pressure which increases PVR.
This can be offset by IPPV.
- Sympathetic stimulation as α agonists.
- Hypervolemia.
- N₂O.

(3) Increase systemic vascular resistance. This decreases the shunt.

So, avoid factors that decrease SVR as:

- Drugs causing VD; - Volatile agents.
 - Histamine releasing drugs.
 - α blockers.
 - Vasodilators.
 - β -agonists.
 - Ca⁺⁺ channel blockers.
 - Phospho-diesterase III inhibitors.
- Hypoxia.
- Severe hypercarbia.

(4) Avoid increase in myocardial contractility as this increases infundibular obstruction against the RV which increases the shunt.

(5) Maintain i.v. volume because a fall in blood volume increases blood viscosity.

Preoperative Management:

As before..... + (C/P, investigations, and complications).

1. **Avoid dehydration** by maintaining oral or i.v. fluid.
2. **Continue β_2 blockers** until the induction of anesthesia if it was used as a prophylaxis against hyper-cyanotic attacks.
3. **Avoid i.m. injections** in premedication as it can cause crying that initiates hyper-cyanotic attack.
4. Severe polycythemic patients should undergo **hemodilution** to Hct of 55-60% preoperatively.
5. Allow heavy premedications.

E.g. - Morphine sulfate.

- Anticholinergics to decrease the bradycardic effect of induction agents.

Intraoperative Management:

Monitoring:

Standard +

Induction:

- Preoxygenation is essential.
- Induction agent:
- **Ketamine (i.m. or i.v.) is of choice** because;
 - It increases SVR.
 - It increases PVR also, but not clinically apparent.

So, the net effect is increased pulmonary blood flow with a decrease in the shunt.

- **Inhalational induction e.g. halothane is accepted** in mild degree shunts, usually with rapid speed onset due to the decreased pulmonary blood flow, but, it must be with care and good O₂ monitoring as they decrease SVR causing hyper-cyanotic attacks.

Maintenance:

Ketamine ± N₂O + Opioid or benzodiazepines + Muscle relaxant + IPPV.

- **Ketamine: advantages** as above.....
- **N₂O:** It should be **only 50%** because of its disadvantages;
 - It has only a little effect on SVR.
 - It increases PVR (but this effect is clinically less than the effect of volatile agents on the decreased SVR so, the net effect is decrease in the shunt so, **N₂O can be used**).
- **Opioids or benzodiazepines:**
Adjust their doses and rates of administration to decrease their effects on SVR and BP.
- **Muscle relaxant:**
 - **Pancuronium** is of choice because
 - It maintains SVR.
 - It increases the heart rate so, it maintains left ventricular CO.
 - Vecuronium, atracurium, pipecuronium, doxacurim can be used because they have little C.V.S. effects.
- **IPPV should be used with care** with;
 - Rapid rate to induce hypocapnia.
 - The airway pressure should be low as possible < 15 mm Hg.
 - High inspired O₂ concentration.

Intraoperative Fluids:

- It should be **maintained** with i.v. **crystalloids** to avoid acute hypovolemia which increases the shunt.
- Give **blood transfusion**;
 - Only when **20%** of blood volume is lost due to associated polycythemia (it is rarely needed, in other pediatric cases blood transfusion is given when 10% of blood is lost).
 - Better to be fresh to provide clotting factors.

Intraoperative Complications:

1. Hypotension (due to SVR): It may cause hyper-cyanotic spells.
2. Infundibular spasm.

So; treatment is as before.....

Postoperative Management:

In ICU, care is taken for pain management and postoperative complications.

CHAPTER 11**ANESTHESIA FOR
NEUROSURGERY****Nervous System Physiology****Cerebral Metabolism****A) O₂ Consumption:**

- The cerebral metabolic rate (CMR) is usually expressed in terms of O₂ consumption (CMRO₂) with an average of 3-3.5(up to 5) ml/100 gm/min (50 ml/min) in adults.

- It is calculated by the Fick's principles

CMRO₂ = Cerebral blood flow x arterial-venous O₂ content difference

B) Glucose Consumption:

- Neuronal cells utilize glucose as a primary energy source even during starvation where ketone bodies are available for the rest of body cells.

- Brain glucose consumption is 5 mg/100 gm/min on average (90% of it is metabolized aerobically).

- During:

a- Acute sustained hypoglycemia:

Irreversible cerebral injury (like hypoxia) occurs.

b- Hyperglycemia: (also harmful)

Increases global hypoxic brain injury by increasing cerebral acidosis.

Cerebral Blood Flow (CBF)

Anatomy: By Circle of Willis

Site: It lies in the inter-peduncular fossa at the base of the brain and around the region of hypothalamus.

Formation:

It is formed from 6 large arteries (3 on either side) and 3 small communicating arteries (one anterior and 2 posterior).

From before backwards; the large arteries are

- Right and left anterior cerebral arteries with one anterior communicating artery between them.

- Right and left internal carotid arteries.

- Right and left posterior cerebral arteries (terminal branches of basilar artery) with two posterior communicating arteries connecting the internal carotid artery with the posterior cerebral artery of the same side.

N.B.; Middle cerebral arteries have no vascular anastomosis with any other arteries (figure 11-1).

Measurement:....."see patient monitors".

Values: in average adult

Global CBF: = 50 ml/100 gm/min (the average).

= 750 ml/min (15-20% of cardiac output).

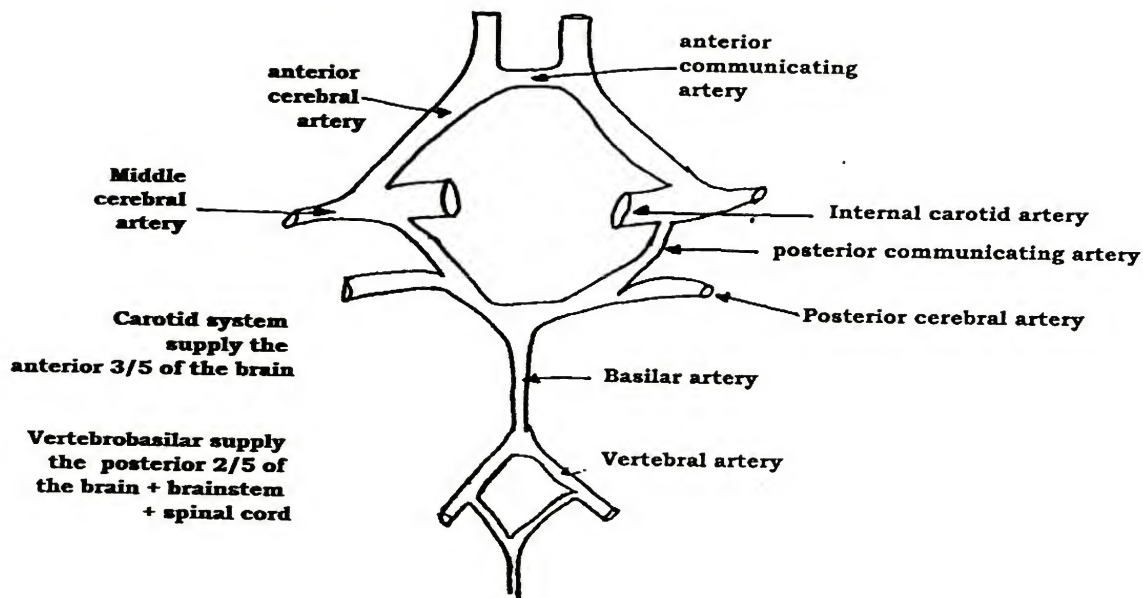


Figure 11-1; Circle of Willis

Critical global CBF:

- The CBF below which cerebral ischemia becomes apparent on EEG (as slowing of EEG) is ≈ 20 ml/100 gm/min.

N.B.; Critical CBF under anesthesia is ≈ 18 ml/100 gm/min (with isoflurane, it is ≈ 12).

CBF < 20 ml/100 gm/min causes a flat isoelectric EEG.

CBF < 10 ml/100 gm/min causes irreversible brain damage.

(\approx = approximately or average)

Regulation of CBF:**- Cerebral Perfusion Pressure (CPP)**

= Mean Arterial Pressure (MAP) – Intracranial Pressure (ICP)

N.B.; We use ICP instead of cerebral venous pressure because:

- o ICP is easier to be measured.
- o Cerebral venous pressure is nearly equal to ICP.

We use cerebral venous pressure when it is greater than ICP.

- Values of CPP: It is normally 90-100 mm Hg.

- o When it is < 50 mm Hg, slowing of EEG occurs (critical CPP).
- o When it is 25-40 mm Hg, flat (isoelectric) EEG occurs.
- o When it is < 25 mm Hg, irreversible brain damage occurs.

- Effect of increased ICP on CPP:

CPP is maintained until the rise of ICP exceeds 30-40 mm Hg where a significant decrease in CPP occurs.

N.B.; Cushing Reflex:

- Increase in ICP causes reflex systemic hypertension and bradycardia which in turn increases CPP, but these effects also increase ICP more.

N.B.; In treatment of closed head injuries:

There is increased ICP so, it is important to give vasopressors therapy to increase MAP. Therefore, CPP is maintained and focal or global ischemia is avoided.

- Cerebral venous pressure is affected by:

1- **Elevated head position** i.e. slight head up decreases CVP which decreases the cerebral venous pressure and ICP.

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- 2- **Elevated intra-thoracic pressure** increases CVP which **increases** the cerebral venous pressure and ICP.
- 3- **Elevated intra-abdominal pressure** as coughing or straining increases CVP which **increases** the cerebral venous pressure and ICP.
- 4- **Elevated blood volume** increases CVP which **increases** the cerebral venous pressure and ICP.
- 5- **Elevated venous tone and venous obstruction** in neck increase CVP which **increases** the cerebral venous pressure and ICP.

(I) Intrinsic Mechanisms:Cerebral Autoregulation

Definition: It is the ability of brain vessels (as coronary and renal vessels) to tolerate wide swings in the mean blood pressure (**between 50-150 mm Hg**) with little changes in the CBF.

As decreased CBF decreases CPP that causes cerebral VD and increases CBF to reach its previous level. and increased CBF increases CPP that causes cerebral VC and decreases CBF to reach its previous level.

Beyond these limits (i.e. < 50 and > 150 mm Hg), CBF becomes pressure dependant so, it changes with the change of blood pressure.

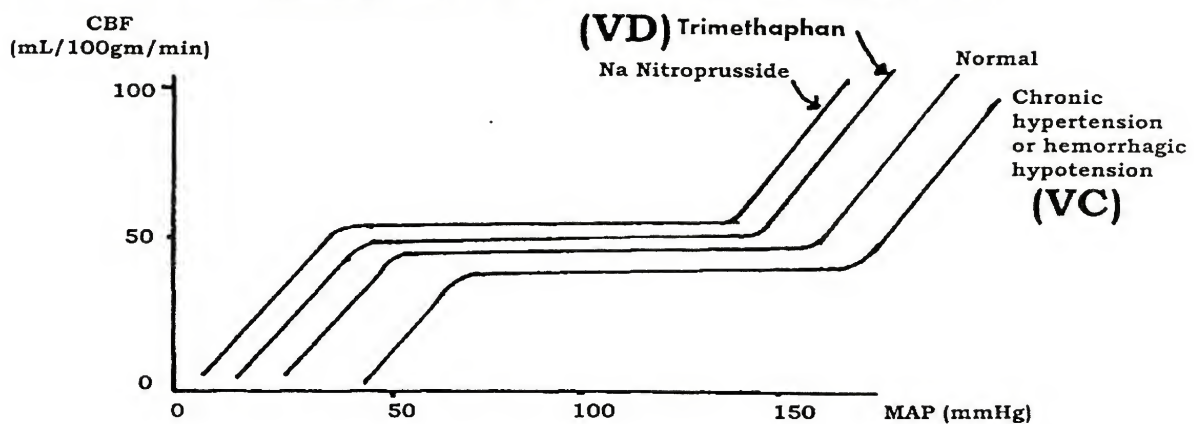
Cerebral Autoregulation Curve: (Causes of Impaired Autoregulation)

Figure 11-2; Cerebral Autoregulation Curve

- a- It is shifted to the right (both upper and lower limits) in;
- Hemorrhagic hypotension as it is associated with excessive sympathetic activity.
 - Chronic arterial hypertension.

This means that:

- Hypertensive patients can tolerate marked increases in MAP much better than normotensive patients.
- MAP of 60 mm Hg, which would be tolerated in normotensive patients, may actually be below the lower limit of autoregulation in hypertensive patients causing cerebral hypoperfusion.

N.B.; Chronic antihypertensive treatment may restore cerebral autoregulation limits to normal.

- b- It is shifted to the left in vasodilator induced hypotension

Na nitroprusside causes more shift to the left than trimethaphan (figure 11-2).

- c- Autoregulation is abolished by;

- Hypoxia, hypercapnia.
- Premature infants.
- Acute increase in ICP as head trauma, intra-cerebral disease.
- Potent volatile anesthetics (except N₂O).
- Inhibition of nitric oxide (NO) synthesis.

N.B.; Inhibition of NO abolishes the cerebral autoregulation i.e. intrinsic mechanism and abolishes cerebral VD in response to hypercapnia, hypoxia and volatile anesthetics i.e. external mechanisms (see later).

- **Mechanisms (Theories):**

(1) Myogenic Theory:

It is the intrinsic response of smooth muscle cells in cerebral arterioles to the changes in MAP i.e. increased MAP causes distension of arteriolar wall that in turn causes contraction of arteriolar vascular smooth muscle. This decreases arteriolar diameter and decreases CBF.

(2) Metabolic Theory:

As release of tissue metabolites e.g. nitric oxide, adenosine, PGs and electrolytes causes VD leading to an increase in CBF.

While release of endothelin (endothelium-derived contracting factor "EDCF") causes VC.

Increased metabolic rate as in pain, anxiety and convulsion increases CBF.

Decreased metabolic rate as with hypothermia, barbiturates and diazepam decreases CBF.

N.B.; Regional CBF parallels the metabolic activity.

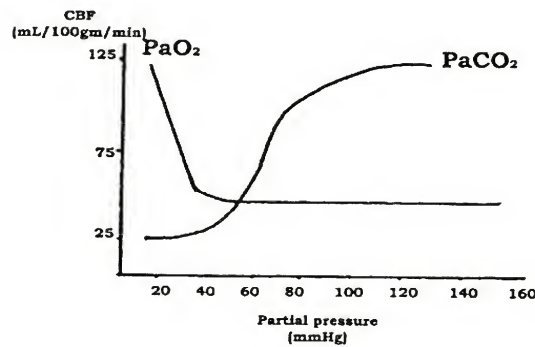


Figure 11-3

(II) Extrinsic Mechanisms:

They are affected by;

(1) Respiratory Gas Tension:

(a) PaCO₂: (the most important)

• CBF is **directly** proportionate to PaCO₂ between tensions of 20-80 mm Hg (figure 11-3).

N.B.; During head injury, mild hyperventilation is needed to decrease PaCO₂ to 30 mm Hg. This causes cerebral VC which decreases ICP so, no need for aggressive hyperventilation which produce sever VC. This causes harmful effect on the already compromised brain.

(b) PaO₂:

- Change in PaO₂ **below 50 mm Hg** causes a marked change in CBF **inversely**.

(2) Extracellular pH (H⁺ ions):

- H⁺ ions in ECF can not cross BBB so, they have a **little effect** on CBF e.g. acute metabolic acidosis.

(3) Temperature:

- CBF varies **directly** with temperature as it changes 5-7% per °C.

(4) Blood Viscosity: is mainly determined by hematocrit (Hct).

- Hct between 30-50% has a **little effect** on CBF. Beyond these limits, CBF varies inversely with Hct.

N.B.;

• **Luxury Perfusion:**

- It is CBF in excess of metabolic requirements.
- It is observed in - Tissues around **tumors** or areas of **infarction**.
 - Tissues manipulated during **surgery**.
 - **Volatile** anesthetic use.

• **Intra-Cerebral Circulatory Steal:**

- It is a paradoxical response to **increased PaCO₂** or **volatile agents** as both decrease CBF to ischemic areas and increase CBF to normal areas of brain.
- As arterioles in ischemic areas are already maximally vasodilated (unreactive), they can not dilate further in response to increased PaCO₂ or volatile agent.

ANESTHESIA FOR NEUROSURGERY• **Inverse Steal or Robin Hood Phenomenon:**

- It is a paradoxical response to **decreased PaCO₂** or **barbiturates** as both increase CBF to ischemic areas and decrease CBF to normal areas of brain.
- Arterioles in ischemic areas remain maximally vasodilated (unreactive) while in normal areas they will VC producing blood redistribution from normal to ischemic areas.

Effect of Anesthesia on CBF:

.....See later, effect of anesthetic drugs on cerebral physiology.

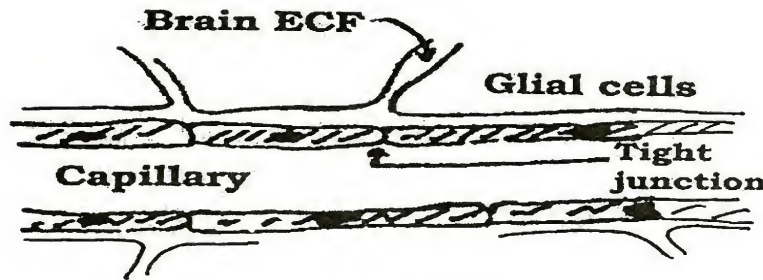
Blood Brain Barrier (BBB)Cause:

Figure 11-4; BBB

The BBB is formed of the junctions between the vascular endothelial cells which are nearly fused (i.e. pores are very rare). This produces a lipid barrier which allows passage of lipid soluble substances (figure 11-4).

Factors Affecting Passage of Substances:

- Size: **Small sized** substances pass more easily.
 - Charge: **Unionized** substances pass more easily.
 - Lipid solubility: **Lipid soluble** substances pass more easily.
 - Degree of protein binding: **Free** substances pass more easily.
- e.g. - Substances freely passing the BBB; CO₂, O₂ and lipid soluble substances as most anesthetics.
- Substances poorly passing the BBB; ions, proteins and large substances as mannitol.

- **Water** freely passes BBB by **bulk flow**

As acute hyper-tonicity of the plasma allows water to pass out of the brain. while acute hypotonicity of the plasma allows water to pass into the brain.

These effects are short lived as Na⁺ equilibration occurs within 2-4 hours, but when these changes are marked, fluid shifts rapidly to the brain so, marked abnormalities of s. Na⁺ or glucose should be corrected slowly.

N.B.; Mannitol, an osmotically active substance does not cross BBB so, it decreases the brain volume.

- **Disruption of BBB is caused by:**

- Hypoxia.
- Head trauma.
- Severe hypertension.
- Sustained seizures.
- Marked hypercapnia.
- Head tumors.
- Cerebral strokes.
- Cerebral infection.

So, fluid movement becomes dependant on the hydrostatic pressure rather than the osmotic pressure.

Cerebro-Spinal Fluid (CSF)

Site: It fills the subarachnoid space between the arachnoid and pia matter.

Formation:

- By active secretion from choroid plexuses (by its ependymal cell lining).

Small amount leaks into the perivascular spaces from the vessels i.e. BBB leakage.

- From • 2 lateral ventricles mainly.
- 3rd and 4th ventricles.
- Rate in adult $\approx 0.3-0.5$ ml/min.

Circulation:

Two lateral ventricles — Foramen of Monro → 3rd ventricle — Aqueduct of Sylvius → 4th ventricle → Cerebro-medullary cistern (Cisterna Magna) through 3 foramina in the roof of 4th ventricle: - Central foramen of Magendie.

- Two lateral foramina of Luschka.

→ Subarachnoid space (figure 11-5).

N.B.; This circulation does not take part in spinal analgesia.

Absorption:

1- Via **subarachnoid villi** (granulation) in subarachnoid space into venous sinuses (figure 11-6).

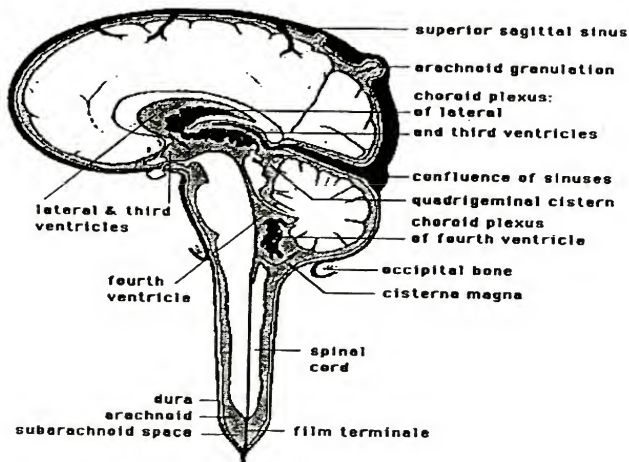


Figure 11-5; CSF circulation

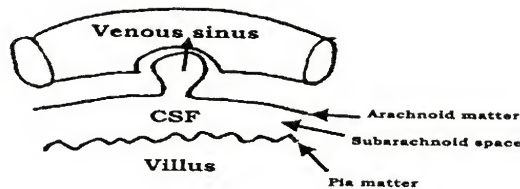


Figure 11-6; CSF absorption

2- Some CSF is absorbed around spinal nerves into spinal veins.

Functions:

- 1- It acts as a **water suspension** to protect the brain and spinal cord **against trauma**.
- 2- To surround certain parts of the brain **with ions containing fluid** so, changes in CSF HCO_3^- concentrations are responsible for changes in respiratory rate and volume mediated by **chemoreceptors**.

Physical Properties:

- It is a clear, colorless fluid, with a specific gravity of 1005.
- Volume: total **125-150 mL** → 100 mL in cerebral subarachnoid space.
→ 25-50 mL in spinal subarachnoid space.
- Pressure: → Lateral recumbent position: **10-15 cm H₂O** (7-10 mm Hg).
→ Sitting or erect position: 30-50 cm H₂O.

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Chemistry: It is protein-free plasma.

	Plasma (mmol/L)	CSF (mmol/L)	
- PH	7.4	7.4	- The same as the plasma.
- Osmolarity	300	Isotonic or slightly hypertonic	
- Na ⁺	142	144-152	- Higher than the plasma.
- Cl ⁻	105	123-128	- Very high.
- Glucose (Fasting)	4	2.5-4.5	- Lower than the plasma.
- K ⁺	5	2.0-3.0	
- Ca ⁺⁺	3	1.1-1.3	
- HCO ₃ ⁻	28	22-30	
- Urea	3	2.0-7.0	
- Protein	60-80 gm/L	0.2-0.4 gm/L	- Very low

Drugs Decreasing CSF Production:

- Carbonic anhydrase inhibitor (acetazolamide).
- Spironolactone.
- Furosemide.
- Vasoconstrictors.
- Corticosteroids.
- Isoflurane.

Intracranial Pressure (ICP)

Normally: (Monro-Kellie hypothesis)

- The cranial vault is a rigid closed "box" except in neonates and infants with a fixed total volume consisting of:

- Brain (1500 gm) 80% (24% solid and 56% water).
- Blood (150 ml) 12%.
- CSF [in cerebral subarachnoid] (100 ml) 8%.

Any increase in one component must be offset by an equivalent decrease in another to prevent a rise in ICP.

Value: Normally ≤ 10 mm Hg.

Measurement: by a small catheter inserted into;

- Lateral ventricles (ventriculostomy catheter).
- Over the cerebral cortex.
- Epidural catheter: as in the lateral recumbent position lumbar CSF pressure normally approximates cerebral CSF pressure.
- It is related directly to intrathoracic pressure so, it has normal respiratory swings.

Intracranial Compliance: (Δ volume / Δ pressure) (**Volume-Pressure Relationship**)

- Small increase in IC volume causes minimal increase in ICP (area 1 to 2) due to adaptive mechanisms (figure 11-7).

1- Initial displacement of CSF from cranial to spinal compartment. Increased CSF absorption and decreased CSF production.

2- Decreased total cerebral blood volume especially venous blood.

- More increase in IC volume causes a great increase in ICP (beyond 2) i.e. the curve is steep with loss of

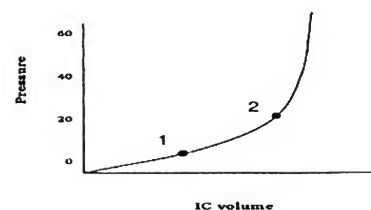


Figure 11-7 Intracranial compliance

- compliance due to; exhaustion of adaptive mechanisms which may cause herniation of the brain.

N.B.; - Slow growth of lesions (e.g. tumors) allows maximum accommodation which is relatively associated with normal ICP.

But, rapid growth of lesions (e.g. hemorrhage) exhausts the adaptive mechanisms with an increased ICP.

Causes of Increased ICP: (Factors causing brain herniation)

(physiologic and pathologic causes)

- a- Increased intra-thoracic pressure: e.g. coughing, straining and PEEP.
- b- Decreased cerebral compliance;
 - 1- IC tumors, hemorrhage, and trauma.
 - 2- CSF outflow obstruction
 - 3- Cerebral vasodilators as sodium nitroprusside, or anesthetic drugs (halothane - isoflurane)
 - 4- Hypercapnia and hypoxia.
 - 5- Hypotension because dilatation of cerebral vessels to maintain CBF (autoregulation) and increase CB volume.
 - 6- Hypertension with impaired autoregulation.
 - 7- Cerebral edema (cytotoxic or vasogenic).

Intracranial Hypertension

Definition: Sustained increase in ICP above 15 mm Hg in supine position.

C/P:

- a- **Early:** asymptomatic
then, headache, effortless vomiting (without nausea), papilloedema, or unilateral pupillary dilatation.
 - b- **Late:**
 - Focal neurological lesions.
 - Change in level of consciousness.
- &/or - Irregular ventilatory pattern.

N.B.; Sites of brain herniation:

- 1- The cingulate gyrus under the falx cerebri.
- 2- The uncinate gyrus via the tentorium cerebri.
- 3- The cerebellar tonsils via the foramen magnum
- 4- Any area beneath a defect in the skull.

Investigation: CT scan

Treatment:

A) Treatment of the underlying cause:

B) Reduction of ICP:

1- Fluid Restriction:

- By: 1/2-1/3 the usual daily requirement of fluids (i.e. 1000-1500 normal saline).
- **Avoid D5%** because glucose metabolism increases brain water which increases ICP and increases cerebral acidosis which increases cerebral injury.
- Value:
 - 1- It increases the osmotic effects (and decreases hypervolemia produced by mannitol).
 - 2- It facilitates induced hypotension.
 - 3- It decreases the incidence of postoperative cerebral edema.

2- Moderate Hyperventilation:

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- Aim: to keep PaCO_2 in the range of 36-40 mm Hg (in acute increases of ICP, decrease the PaCO_2 to 30-35 mm Hg transiently then return it to the normal range).

- Avoid hypocapnia as it causes severe cerebral VC which increases cerebral ischemia.
- Avoid hypercapnia as it causes steal phenomenon in focal ischemia. It worsens intracellular acidosis and increases ICP.

- Mechanism:

1- The decrease in PaCO_2 causes compensatory respiratory alkalosis against the acidosis of ischemia i.e. increased IC and EC pH.

2- The decrease in PaCO_2 causes a decrease in CBV which in turn decreases ICP.

3- The decrease in PaCO_2 causes VC in non-ischemic areas which in turn causes redistribution of the blood to ischemic areas (inverse steal effect).

3- Decrease Cerebral Venous Pressure:

- By: • Head up tilt.

- Avoid coughing and straining.
- Avoid extreme flexion or twisting of the neck.

4- Cerebral Dehydrating Measures:

a- Hyper-osmolar agents (osmo-diuretics): (it must be with urinary bladder catheters).

They increase plasma osmolarity which shifts the fluid from the brain cells to the plasma.

(i) **Mannitol 10, 20, 25%** (of choice)

- Dose: 0.25-1.0 gm/Kg infused over 10-20 min (maximally 4 gm/kg/day).

- Onset: 10-15 min.

- Duration: 2 hours.

- Advantages:

- 1- Less irritant than urea.
- 2- Less rebound increase in brain volume than with urea.
- 3- Makes the brain softer and more easily retractable.

- Disadvantages:

- 1- Transient hypervolemia so, it is contraindicated in congestive heart failure or impaired renal function and it may increase surgical bleeding.
- 2- When intra-cerebral hematoma is suspected, mannitol may shrink healthy brain tissues leading to expansion of intra- and extra-cerebral hematomas so, it is contraindicated in cerebro-vascular lesions.
- 3- Excessive mannitol draws H_2O from the heart cells producing irreversible cardiac arrest so, it is contraindicated in cardiac arrest.
- 4- In elderly patients, if given rapidly, it may cause subdural hematoma due to rupture of bridging veins entering the sagittal sinus.
- 5- If it is used > 4 days or there is a damaged BBB, mannitol crosses the BBB causing rebound effects. So, it is contraindicated in vasogenic brain edema.
- 6- Vasodilatation which may cause - Intracranial VD that increases CBF and ICP.
- Extracranial VD that causes hypotension.

This occurs especially in rapid infusion of mannitol 25%, but very rare in slow infusion of mannitol 10-20%.

7- On prolonged use;

- Electrolyte depletion occurs.

- Plasma osmolarity may increase and exceed 320 mosm/L producing neurological and renal dysfunction. So, it is contraindicated with prolonged use.

(ii) **Urea 30%:**

- Dose: 1-1.5 gm/kg infused over 60 min.

- Disadvantages:

- 1- Very irritant to veins.
- 2- Rebound increase in brain volume may occur.

(iii) Glycerol 10%:

- Dose: 0.5-1.0 gm/kg i.v. or oral.

(iv) Isosorbide.

- (v) Hypertonic saline 7.5%:** In refractory cases.

b - Diuretics: (with urinary bladder catheter)

- Loop diuretics as furosemide (1 mg/kg, onset 2-10 min).
- It is of choice in patients with congestive heart failure and renal impairment.

- Action:

- 1- Diuresis causes brain dehydration.
- 2- It decreases CSF formation.
- 3- It decreases brain edema.

N.B.; Combined osmotic and loop diuretics cause a synergistic effect, but require close monitoring of s. K^+ .

c- Steroids: Dexamethazone:

- It is effective in localized cerebral edema surrounding tumors.
- Dose: 10 mg i.v. followed by 4 mg im/6 hours.
- Action: (it needs 12-36 hours to decrease ICP).
 - 1- It causes simple brain dehydration.
 - 2- It promotes repair of the BBB so, it is used in vasogenic brain edema especially that due to IC tumors (not effective in focal or global ischemia or head trauma)
 - 3- It acts as a free radical scavenger.
 - 4- It inhibits lipid peroxidation producing a decrease in free fatty acid accumulation.

5- Drugs to increase cerebro-vascular resistance: (i.e. drugs causing cerebral VC)

As thiopentone and lidocaine, both cause cerebral VC and lead to a decrease in CBF and ICP.

6- Hypothermia: (Mild up to 34 °C) (see later)

- Action: Decreasing brain temperature causes;
 - o Decreased brain metabolism, CBF, and ICP.
 - o Decreased CSF formation.
- Indications: Surgery on cerebral vasculature that requires long periods of cerebral ischemia.

7- Decreasing CSF Volume:

- 1- Ventricular tap (ventriculostomy).
- 2- Spinal drainage (by a rate < 5 ml/min).

Disadvantages:

- If a higher rate is drained, the following may occur;
 - Arterial hypertension and arrhythmia (bradycardia, cushing reflex).
 - Rebound increase in ICP.
 - It precipitates medullary coning.
- 3- Decreasing CSF production is done by;
 - 1- Carbonic anhydrase inhibitors, acetazolamide (Diamox).
 - 2- Diuretics.
 - 3- Hypothermia.

8- Lastly Surgical Decompression:

Cerebral Edema

Definition: An increase in the water content of the brain.

Types:

1- **Vasogenic:** (the most common)

- Mechanism: **Disruption of BBB** causes leakage of intravascular proteins into the brain.
- Causes:
 - Hypoxia.
 - Head trauma.
 - Severe hypertension.
 - Sustained seizures.
 - Marked hypercapnia.
 - Head tumors.
 - Cerebral strokes.
 - Cerebral infection.

2- **Cytotoxic:**

- Mechanism: failure of brain cells to actively extrude Na^+ with progressive cellular swelling.
- Cause: metabolic insults e.g.
 - Hypoxia (cardiac arrest).
 - Ischemia (stroke).
 - H_2O intoxication (as acute decrease in s. osmolarity causes IC movement of H_2O).

3- **Interstitial:**

- Mechanism: Entry of CSF into the brain interstitium.
- Cause: obstructive hydrocephalus.

Treatment

As IC hypertension except 7 and 8.

Effect of Anesthetic Agents on Cerebral Physiology

- All **inhalational agents**;
 - Decrease CMR especially iso-, des- and sevoflurane.
 - Increase CBF (and CBV) and ICP, the least increase in CBF is by **isoflurane and sevoflurane** so, they are **of choice** in patients with decreased IC compliance. Therefore, on increased doses e.g. > 1 MAC (for halothane and isoflurane) and > 1.5 MAC (for sevoflurane), autoregulation is abolished.
 - CNS action of inhalational agents.....see before in pharmacology.
- All **i.v. agents**;
 - Decrease CMR especially thiopentone and etomidate.
 - Decrease CBF (and CBV) and ICP especially **thiopentone** so, (it is **of choice** in patients with decreased IC compliance), with the exception of **ketamine**, it increases them so, it is **contraindicated**.
- **Fentanyl** decreases ICP so, it is **of choice** in decreased IC compliance.
- Other drugs:
 - 1- **Vasopressors**:
 - With normal autoregulation, they increase CBF only if MAP beyond 150 mm Hg.
 - In absence of autoregulation, they increase CBF by their effect on cerebral perfusion pressures.
 - 2- **Vasodilators**:
 - They increase CBF and CBV which in turn increase the ICP, except trimethaphan and α blockers which have little or no effect.
 - 3- **Dopamine**:
 - At doses of $< 2 \mu\text{g/kg/min}$, little or no effect on CBF is present.
 - At doses of $2-6 \mu\text{g/kg/min}$, CBF is increased.
 - At doses of $7-20 \mu\text{g/kg/min}$, CBF is decreased.
 - 4- **Muscle Relaxants**:
 - They have an **indirect** effect on the brain

As hypertension and histamine mediated cerebral VD increases ICP.

Hypotension decreases ICP.

- Succinylcholine causes cerebral VD which increases the ICP.

This effect is attenuated by thiopentone, hyperventilation, and defasciculating dose of non depolarizing muscle relaxants.

Brain Protection

Pathophysiology of Cerebral Ischemia

The strategies for brain protection are based on the understanding of the pathophysiology of cerebral ischemia.

Causes of Cerebral Ischemic Hypoxia:

a- **Global Insult:** i.e. It affects all the brain.

E.g.; - Cardiac arrest.

- Severe respiratory failure.
- Severe shock.
- Severe hypoglycemia.

b- **Focal insult** i.e. It affects part of the brain.

E.g.; - Head trauma or injury.

- Vascular stenosis (atherosclerosis).
- Vascular occlusion (embolism).
- Vascular spasm (hemorrhage).

Strategies for Brain Protection

A) Treatment of the Cause of Brain Ischemia:

Either - Global.

- Focal.

B) General Measures: (for global and focal ischemia).

1- Keep normal O₂ carrying capacity:

- by: - Keeping hematocrit (Hct) between 30-34%.
- Keeping normal PaO₂.

2- Keep normal blood glucose:

- The best blood glucose is **100-150 mg/dL**. So, it should be measured every 2 hours.
- Mechanism: normoglycemia decreases intracellular lactic acidosis (which occurs with hypo- and hyperglycemia). This maintains normal cellular permeability and decrease cellular edema.

C) Decrease CMRO₂:

1- Hypothermia: (for global and focal ischemia).

- It is the most effective.
- Mechanisms: It decreases all biochemical processes;
- It decreases basal and electrical metabolic rate which in turn decreases CBF and ICP.
- It decreases CSF formation.
- It decreases excitatory neurotransmitter release which in turn decreases Ca⁺⁺ influx.
- It decreases accumulation of lipid peroxidation products and decreases the free radicals.
- The optimum temperature is:
- Mild hypothermia (33-36 °C). It is preferred as there are less side effects.

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- Moderate hypothermia (29-32 °C).
- Profound hypothermia (15-28 °C). It is avoided as it increases the toxic metabolites and increases cardiac depression.

N.B.; It is now suggested that **prevention of hyperthermia** is associated with **better results than maintaining hypothermia** as hyperthermia has a bad effect on the brain. Therefore, hyperthermia in patients with cerebral ischemia should be treated aggressively.

2- Anesthetic Agents: (mainly for focal ischemia)

Mechanism: they decrease the electrical activity of the brain resulting in decreased electrical metabolic rate (no effect on the basal metabolic rate).

(a) Volatile Anesthetics:

- Isoflurane.
- Desflurane.
- Sevoflurane (the best for carotid endarterectomy).

They affect different parts of the brain to variable extents.

(b) I.v. Anesthetics:

• Thiopentone:

- Dose: iv infusion of 1-5 mg/Kg/hr (i.e. nearly 500 mg "one vial"/hr for adults)

- Mechanisms:

1- It decreases electrical activity of the brain resulting in a decrease in the electrical metabolic rate. It has a uniform effect on brain parts (i.e. it increases GABA activity).

2- It has an anticonvulsant action.

3- It blocks NMDA and AMPA receptors resulting in a decrease in Ca^{++} influx.

4- It has an antioxidant action as it inhibits free radical formation.

5- It increases the activity of the hexose mono-phosphate shunt (HMP shunt).

6- It decreases brain edema by producing;

• Peripheral VD that decreases systemic vascular resistance. This decreases ABP which in turn decreases CBF and ICP.

• Selective cerebral VC which decreases CBF and ICP.

7- It is a Na^{+} channel blocker.

8- Inverse steal or Robin-Hood syndrome (see before).

9- It decreases glucose transfer across the BBB.

• **Propofol**: affects different parts of the brain to variable extents.

• **Ketamine**: Although it has a little effect on CMR, but it blocks the action of glutamate at NMDA receptors.

N.B.; **Etomidate** is avoided, it was suggested to produce brain protection, but recently it was proved that the standard **propylene glycol** used in formation of etomidate induces cerebral hypoxia and tissue acidosis leading to harmful effects.

D- Increase CBF and CPP: (for global and focal ischemia)

Keep CPP within a range of > 65-70 mm Hg. The increase in CPP is produced by;

1- **MAP**: should be normal or slightly elevated.

2- **Blood viscosity** should be decreased, although this may decrease O_2 carrying capacity of blood so, the best Hct is 30-34%.

3- Decreasing ICP by;

- Fluid restriction.....
- Moderate hyperventilation.....
- Decrease cerebral venous pressure.....
- Cerebral dehydrating measures.....
 - Hyperosmolar agents.....

- Diuretics.....
- Glucocorticoid steroids (Dexamethazone).....
- Hypothermia.....
- Decrease CSF volume.....
- Lastly surgical decompression.....

E- Specific Agents: (for specific conditions)

(1) Ca⁺⁺ Channel Blockers:

- E.g.: **Nimodipine** and **nicardipine**.
- Effective in- Hemorrhagic and ischemic strokes
 - Subarachnoid hemorrhage (it decreases vasospasm).

(2) Na Channel Blockers:

- E.g.: **lamotrigine** (anticonvulsant) and **lidocaine** (intra- and postoperative).
- Effective in- Global and focal ischemia as subdural hematoma, head trauma and middle cerebral artery occlusion.

(3) Methyl Prednisolone:

- Dose: 30 mg/Kg bolus then 5.4 mg/Kg/day for 2 days given within 8 hours from the insult.
- Effective in: spinal cord injury.

(4) 21-Aminosteroids:

- E.g.: **Tirilazad**.
- Effective in: subarachnoid Hge (doubtful results).
- Mechanisms: potent inhibitor of O₂ free radical induced lipid peroxidation.

(5) N- Methyl D- Aspartate (NMDA) Receptor Antagonists:

1- **Remacemide:** It decreases the incidence of strokes in patients undergoing coronary artery bypass surgery.

2- **Mg⁺⁺:** It is used in acute ischemic stroke patients and traumatic brain injury by **Field Administration of Stroke Treatment-Magnesium (FAST-MAG)**. It is used soon after trauma "4 gm i.v". It gives good results.

3- **Xenon:** It has some neuro-protective action.

4- **Ketamine:** See before.....

5- Others:• Dextro-methorphan.

- Dextrophan antitussives.
- MK-801
- Aptiganol.
- N₂O: it is considered as a neurotoxic agent

All are NMDA antagonists i.e. they decrease the release of glutamine (excitatory neurotransmitter) so they prevent neuronal damage from excessive glutamine, but they also decrease GABA release (inhibitory neurotransmitter) therefore, **general dis-inhibition** occurs resulting in more neuronal damage and high side effects as hallucinations.

Future Concepts in Brain Protection

(1) Nitric Oxide (NO):

- In mice, without nNO, there is a decrease in the infarct size after focal ischemia. While in those without eNO, there is an increase in the infarct size after focal ischemia.
- So, **designing drugs that selectively inhibit nNOS while stimulating eNOS will decrease ischemic effects on neuronal tissues.**

(2) Cerebral Preconditioning:

- It is induction of controlled conditions that subject the brain to stress and allowing the brain to produce **endogenous proteins of repair e.g. erythropoietin (EPO)** that protect the brain later on when it is subjected to periods of ischemia or hypoxia.
- Recent research shows the following **evidence;**

ANESTHESIA FOR NEUROSURGERY

- Inducing cerebral preconditioning 18-24 hours before elective neurosurgery is beneficial.
- Transient ischemic attacks induce ischemic preconditioning in humans.

- **Methods of induction of preconditioning:**

Still clinically acceptable means are under research.

Experimental results suggest that preconditioning can be induced by;

- **Preoperative hyperbaric oxygen therapy.**
- **Electro-convulsive therapy.**
- **Potassium channel openers as diazoxide.**
- **Erythropoietin (EPO):** It is the most promising.

Anesthesia for Craniotomy

For intracranial masses

Causes of Intracranial Masses:

- 1) Congenital.
- 2) Tumor (benign or malignant).
- 3) Infection (abscess or cyst).
- 4) Vascular (hematoma or malformation).

N.B.; • **Supra-tentorial masses** cause seizures, hemiplegia, aphasia and an increased ICP.

- **Infra-tentorial masses** i.e. masses in the posterior fossa containing the medulla, pons, and cerebellum.

Preoperative Management:

Preoperative Evaluation:

1) Neurological Assessment: should be documented for:

- C/P of the lesion as above.....
- Mental status (by Glasgow coma scale).
- Sensory or motor deficits.
- Presence of muscle wasting (for hyperkalemia).
- Assess the ICP for intracranial hypertension.

2) Presence of Coexisting Diseases:

E.g., hypertension, DM, ischemic heart and manage.

3) Drug Therapy: for precautions and side effects.

Especially; • Corticosteroids as they can cause induced hyperglycemia.

- Diuretics as they can cause electrolyte imbalance.

- Anticonvulsant serum levels should be checked.

4) Preoperative Investigations:

Critically ill patients should be closely monitored during the investigations.

Restless or uncooperative patients may need GA.

Routine: +

- CT and MRI: For assessment of the brain lesion.
- ICP measurement: if increased ICP is suspected.

Preoperative Patient Preparation:

1) Measures to decrease ICP: They can be started preoperatively if ICP is high.

As:

- Fluid restriction.
- Decreasing cerebral venous pressure by head up tilt.....

- Cerebral dehydrating measures as mannitol, diuretics.....
 - Drugs that decrease cerebro-vascular resistance as thiopentone, lidocaine.....
 - Steroids: dexamethazone for brain tumors, or abscess (not used in head trauma).
 - Decreasing CSF volume as ventriculostomy just before induction.....
- (For more details see CNS physiology).

2) Measures to decrease venous thrombo-embolism due to lengthy operations.
See respiratory anesthesia (pulmonary embolism).

3) Medications, as steroids, anticonvulsants, antihypertensives and anti-anginal
 should be continued till time of surgery.

Premedications:

1) Sedatives as oral diazepam or i.m midazolam.

- Conscious patients with normal ICP should receive small doses to prevent anxiety which can cause hemodynamic instability.
- Patients with increased ICP and altered conscious level should not receive any sedatives as they may cause hypo-ventilation and hypercarbia which in turn increases CBF and increases ICP further.

2) Prophylactic antibiotics may be given.

Intraoperative Management:

Aim: To maintain adequate cerebral perfusion.

Monitoring:

Standard +

1) UOP: for - the frequent use of diuretics.
 - the long duration of surgery.
 - guidance of fluid therapy.

2) Body Temperature: - for the lengthy surgery.
 - If hypothermia is used to decrease ICP.

3) Invasive BP Monitoring: to ensure optimum cerebral perfusion.

- Many neuro-anesthesiologists zero the arterial pressure transducer at the level of the head (external auditory meatus) instead of the RA to facilitate calculation of cerebral perfusion pressure.

4) Arterial Blood Gas Analysis:

To regulate PaCO₂, so enabling proper control of ICP (EtCO₂ alone is not enough).

5) CVP Monitoring:

- For - Patients receiving vasoactive drugs.
 - Judging fluid therapy and volume status.
 - Aspiration of venous air embolism if it occurs (with its tip in the RA).
- Some avoid the use of the internal jugular vein for catheterization because:
 - There is a risk of carotid puncture.
 - It may interfere with venous drainage from the brain.

6) Pulmonary Artery Catheter:

- For: - Assessing fluid therapy and volume status.
 - Monitoring of CO in patients who have had preoperative cardiac problems.
- Care must be taken to use minimal head-down necessary to access the central venous circulation, because severe trendelenburg position has a deleterious effect on ICP and CPP.

7) Neuro-muscular Monitoring:

- To avoid intraoperative straining and coughing.
- It is done on the non-affected side in patients with hemiparesis because the paresis makes the twitch response resistant and suppressed.

ANESTHESIA FOR NEUROSURGERY**8) Cerebral Function Monitoring** (not standard monitors in most hospitals)

a) EEG.

b) Evoked Potentials: as SSEPs, and visual evoked potentials.

Brainstem auditory evoked potentials sometimes is used to prevent the 8th cranial nerve injury during **posterior fossa craniotomy** e.g. acoustic neuroma, and aneurysm.

(For more details see CNS monitoring)

9) ICP Monitoring:

- It is done in cases with increased ICP by a small catheter inserted under L.A.;
- Into lateral ventricle (ventriculostomy).
- Over the cerebral cortex.
- Epidural catheter (the most common) because lumbar CSF pressure normally approximates cerebral CSF pressure.

10) Monitoring for Venous Air Embolism (in posterior fossa craniotomy)

As:

- Precordial or esophageal stethoscope.
- Precordial Doppler ultrasound probe.
- Trans-esophageal echocardiography.

.....See details in anesthesia with respiratory diseases (pulmonary embolism).

Choice of Anesthesia:**A) Local Anesthesia (Awake Craniotomy):****Indications: (and Advantages)**

- 1- Increased ICT with **slight operative intervention** e.g. burr hole biopsy.
- 2- When **the patient's cooperation is required** as localization of subjective phenomenon e.g. • **Speech monitoring:** usually done with LA as it needs full patient's cooperation.
 - Epilepsy surgery.
- 3- **Motor mapping** when GA is used and direct cortical electrical stimulation is done (so, care with the use of muscle relaxants is taken). This **allows maximal tumor resection** therefore decreasing postoperative neurological deficits.
- 4- Increased ICT for some **emergency craniotomies** e.g. middle meningeal artery ligation.
- 5- **Very poor general condition of the patient** which contraindicates general anesthesia.

Disadvantages:

- 1- It is unsuitable for uncooperative patients.
- 2- It is unsuitable for some conscious patients due to the strain produced by the long duration of surgery.

Anesthetic Management:**Preoperative Management:**

Beside all the preoperative management of ordinary craniotomies;

• The **anesthesiologist must explain** to the patient that he or she will be awake during part if not all of the procedure and that this is required so that the healthy part of the brain can be identified and not injured. It is important to review with the patient what will be required from him or her such as the questions that may be asked to assess the speech center and tasks such as "move your toes".

• **Premedication:**

- **Avoid sedatives** or only give a minimal dose when full patient's cooperation is needed. I.v. diazepam is given to decrease the risk of epilepsy if it is suspected.
- **Clonidine** may be used as a premedication.
- **Anti-emetics** as ondansetron or metoclopramide to avoid intraoperative emesis can be used because vomiting may injure the awake patient.

Intraoperative Management:

Beside all the intraoperative management of ordinary craniotomies;

a) If the patient is awake during the whole procedure:

- **Minimal doses of sedatives** are needed. Propofol, midazolam, remifentanyl or alfentanil are commonly used for sedation and analgesia.

- **LA infiltration** of skin and scalp with 2% lignocaine + adrenaline 1:100 000.

N.B.; • Bone is slightly sensitive, but periosteum is very sensitive.

- Brain tissues (cranial contents) are insensitive except;
 - Dura mater attached to the bone of the skull.
 - Dura around middle meningeal artery.
 - Nervous spinous tissues.
 - Trigeminal ganglia.

b) If wake up Test is required:

- GA is induced with LMA for craniotomy, followed by intraoperative awakening for neurological assessment, followed by GA with LMA until completion of surgery "see before CNS monitoring".

Generally, anesthetics which are used should **not interfere with the EEG** as;

- **< 0.5 MAC of isoflurane** with 2-4 µg/kg fentanyl.
- **Full muscle relaxation** is needed to avoid muscular artifacts, but it is **avoided if motor mapping** is planned.
- If the BP rises due to a lighter plane of anesthesia, labetalol or esmolol is recommended (nitroprusside or hydralazine are not recommended as both may produce changes of cerebral blood flow, as they increase HR).
- If the surgeon asks for more patient cooperation, reversal of medication could be needed e.g. flumazenil (for sedatives) or naloxone (for narcotics).
- If the patient complains of pain, small doses of remifentanyl 0.01 to 0.05 mg/Kg/min for 3-5 minutes combined with propofol 15 µg/Kg/min are effective in conscious sedation.

Postoperative Management:

All the postoperative management of the ordinary craniotomies are done.

B) General Anesthesia: the most commonly used.**Induction:**

Smooth induction to avoid further increase in ICP.

- **Preoxygenation** with voluntary hyperventilation (in cooperative patient) to decrease ICP.
- **Avoid pressor (stress) response of intubation** by;
- Deepening anesthesia by volatile agents especially isoflurane.

- I.v. opioids
- Decreasing the laryngoscopic time.
- Lidocaine i.v., topical anesthesia of the airway, intra-tracheal, or spray.
- I.v. β blockers (see details in airway management)

The use of hypotensive agents as nitroprusside, or nitroglycerine should be avoided as they both cause cerebral VD which further increases CBF and ICP.

- **Induction agents:** Avoid drugs which increase CBF and ICP.
- **Thiopentone:** It provides greater **brain protection** as it decreases CBF and ICP.
- Propofol: It decreases CBF and ICP. It also allows early recovery.
- **Avoid ketamine:** as it increases CBF and ICP.
- **Avoid inhalational induction in children** as;
 - It increases CBF and ICP.
 - It makes the child distressed which further increases ICP.

ANESTHESIA FOR NEUROSURGERY**- Muscle relaxants:**

• Non-depolarizing muscle relaxants: as rocuronium, vecuronium, pipecuronium or doxacurium can be used because;

- They have no effect on CBF and ICP. The **nerve stimulator** should be used to ensure adequate muscle paralysis to avoid coughing with intubation.

- They have no effect on hemodynamic states.

• Succinylcholine:

It is used especially if there is suspected difficult intubation or potentially full stomach.

It is used with the following precautions;

It may increase ICP by fasciculations so; defasciculation dose of non-depolarizing muscle relaxants may be given.

In patients with significant muscle wasting and paralysis due to the risk of hyperkalemia.

N.B.; Rapid sequence crush induction is done if there is a risk of aspiration. Some anesthesiologists consider patients with an increased ICP to have an increased risk of aspiration due to the presence of vomiting so; do crush induction.

- E.T.T.:

• Armored latex (non-kinkable) tube is used.

• It should be well secured.

• It should be re-checked after positioning.

Position:**a) Supine Position:**

- For frontal, temporal and parieto-occipital craniotomy.

- Precautions:

• The head is usually elevated **15-30 degrees** to facilitate venous and CSF drainage.

• The head may be turned to the side to facilitate exposure, but **avoid excessive twisting** of the neck as this may cause;

- Jugular venous drainage obstruction resulting in increased ICT.

- Arterial compression in the elderly resulting in vertebro-basilar insufficiency.

b) Modified Lateral Position

(Three-quarter prone-park bench): →

c) Prone Position:

→ For posterior fossa craniotomy.

d) Sitting Position:

→

- **Sitting position** is preferred by most surgeons (but not by anesthesiologists) because: • It allows better access to the tumor especially large or midline tumors.

• It increases venous and CSF drainage.

- Technique:

• Patient is actually semi-recumbent in the standard sitting position as the back is elevated to 60 degrees while the legs are elevated with the knees flexed to the level of the heart to prevent venous pooling and decrease the risk of venous thrombo-embolism.

• The head is fixed in a three-point holder (**May field holder**) with the neck flexed while the arms remain at the sides with the hands resting on the lap (figure 11-8).

- Contraindications of the sitting position:

a- Absolute: • Intra-cardiac defects.

• Pulmonary A-V malformation.

• RA pressure > LA pressure.

• PFO.

• Cerebral ischemia when upright and awake.

b- Relative: • Severe hypovolemia or uncontrolled hypertension.

• Extremes of age.

- Severe cachexia.
- Severe hydrocephalus.
- High lesion vascularity.
- COPD.

- Complications of this position:

1. **Postural hypotension:**

- Due to
 - Pooling of the blood into the lower extremities.
 - The intentional volume depletion induced by fluid restriction and diuresis.
 - GA blunts or abolishes the compensatory sympathetic reflexes.
- So, • **Gradual positioning with BP monitoring** is essential.

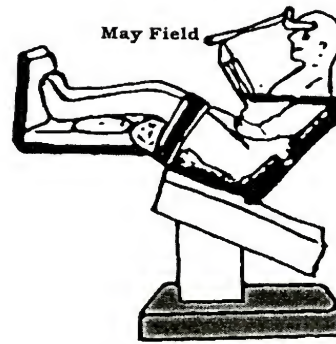


Figure 11-8; Sitting position

- **Wrapping the legs with elastic bandages** (from the feet to the upper thigh) or elastic stockings before positioning to decrease venous pooling (and to decrease D.V.T.).
- Using **light anesthesia during positioning** helps in maintaining sympathetic tone.
- **Small doses of a vasopressor** as ephedrine or phenylephrine may be used (They are preferred than i.v. infusion of large amounts of fluids).

2. **Hypertension:**

- It may occur due to the pins of the head-holder. So, it is better to infiltrate local anesthetics at the sites of the pins.

3. **Avoid injury of pressure points:** e.g. elbow, ischial spines, or forehead.

- So, protect them by foam padding.

4. **Avoid excessive neck flexion** as;

- It impedes venous drainage resulting in an increase in the ICP and causes swelling of the upper airway.
- Rarely, compression of cervical spinal cord occurs, especially if the patient has preexisting cervical spinal stenosis, causing quadriplegia.

5. Increased incidence of

- Venous air embolism.
- Pneumocephalus.

Generally, during any positioning:

- E.T.T. and i.v. cannulas should be well secured. All the breathing circuit connections and i.v. lines should be checked as both the patient and the connections are almost completely covered by surgical drapes.
- Recheck the proper position of the tube after positioning.
- Cover the eyes.
- Shaving of the head is usually done after induction and before positioning.

Maintenance:

Either $O_2 \pm N_2O$ + opioids + low concentration volatile agents + muscle relaxants and controlled ventilation.

or total i.v. anesthesia + muscle relaxant and controlled ventilation.

- **N₂O:**

It is **avoided** with:

- Sitting position as it increases venous air embolism and pneumocephalus.

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- IC cyst.
- Air encephalography (not done now after the advance of CT and MRI).
 - It increases CBF, ICP, and CMR. These effects occur when it is used alone, but in combination with other agents, variable effects occur.
 - It decreases the neuro-protective action of other agents as thiopentone or isoflurane.
- **Opioids:**
 - Especially short acting opioids as fentanyl, sufentanil, and alfentanil are used to avoid postoperative respiratory depression.
 - They have little or no effects on CBF and ICP. Fentanyl may decrease ICP So, it may be preferred.
- **Low Concentration Volatile Agents:**
 - Some avoid them as all increase CBF and ICP especially before opening the dura. They are used if there is no risk of increased ICP.
 - **Isoflurane** is of choice because it has the least effects on CBF and ICP.
- **TIVA:** (Propofol + alfentanil infusions):
 - It is used if there is a risk of increased ICP. It is preferred by some authors because;
 - 1- It allows **rapid postoperative recovery** and so, rapid assessment.
 - 2- It allows **intraoperative awakening** of patients to move in response to command, for neurological assessment e.g. during spinal surgery, trigeminal nerve surgery.
 - 3- It **decreases the incidence of postoperative shivering** and postoperative nausea and vomiting.
- **Muscle Relaxants:** as in induction.
- **Controlled Ventilation:**
 - **Moderate hyperventilation** is needed to maintain PaCO_2 between 25-30 mm Hg (recently 35-40 mm Hg is maintained) to decrease ICP.
 - Avoid severe hypocapnia as it causes cerebral VC which increases cerebral ischemia.
 - Avoid hypercapnia as it causes
 - Cerebral VD resulting in increased CBF and ICP
 - Steal phenomenon in focal cerebral ischemia.
 - Worsening intracellular acidosis.
- Avoid PEEP and high airway pressures as both increase CVP which in turn increases ICP.

Intraoperative Fluid Management:

Amount:

- Intraoperative fluid should be **moderately restricted** (i.e. below the calculated amount) especially in patients with severe brain edema or increased ICP because;
 - This allows greater osmotic effects of mannitol in a smaller circulation volume.
 - Mannitol causes circulatory overload so, if the blood volume is large, it may increase the risk of pulmonary edema.
 - It facilitates induced hypotension in vascular lesions.
 - It decreases the risk of postoperative edema.
- Types:
 - Isotonic crystalloids e.g. normal saline is used for maintenance (avoid hypotonic solutions e.g. lactated ringer as this decreases plasma osmolality).
 - Colloid solutions e.g. human albumin is used to restore intravascular volume deficits (if only crystalloids are given they cause dilutional effects i.e. they decrease the colloidal osmotic pressure of plasma resulting in an increase in the brain edema so, colloids should be used with crystalloids).

- Hypertonic solutions e.g. mannitol, urea, hypertonic saline.
- Blood transfusion:

Care should be taken as occult blood loss may occur underneath the surgical drapes or on the floor.

- Avoid:

- Hypotonic solutions
- Glucose containing solutions because;
 - Hyperglycemia may already be present due to corticosteroids.
 - Hyperglycemia increases global hypoxic brain injury by increasing cerebral acidosis.

Q: What are the fluid managements during craniotomies?

A: Discuss; • Preoperative fluid restriction.

- *Intraoperative fluid types including mannitol and amount (mention the method of calculation of fluid therapy) with discussing methods of fluid therapy monitoring.*
- *Postoperative fluid management.*

Intraoperative Complications & Problems:

1) Brain Protection Methods:

- 1- Keep normal O₂ carrying capacity - keep Hct between 30 – 40%.
 - keep normal PaO₂.
- 2- Keep normal blood glucose between 100-150 mg/dL so; measure it / 2 hours.
- 3- Mild hypothermia (33-36°C).
- 4- Anesthetic agents; thiopentone (it is the best).
 - See details CNS physiology.....

2) Increased ICP (IC hypertension):

- Measures to decrease ICP as before.....

3) Intraoperative Hypertension:

- Due to: - Surgical stimulation.
 - Increased ICP which is associated with bradycardia (cushing reflex).
- Treatment:
 - 1st deepen the anesthesia by sub-MAC doses of isoflurane.
 - β blockers as esmolol or labetalol are given (they also increase HR).
 - Avoid vasodilators as nitroprusside, nitroglycerine, Ca⁺⁺ channel blockers or hydralazine especially before opening the dura as they produce cerebral VD which in turn increases CBF and ICP.

4) Intraoperative Hypotension:

- Due to: - Hypovolemia or blood loss so, assess and manage them.
 - Or - VD.
- Treatment: is by vasopressors as ephedrine or phenylephrine. Both are preferred than i.v. fluids.

5) Intraoperative Bradycardia:

- Due to • Cushing reflex: as increased ICP increases the BP and decreases the HR.
 - Or • Vagal reflex due to - Stimulation of cranial nerve roots.
 - Vascular surgery around circle of Willis and internal carotid artery.
- Treatment: immediate anticholinergic drugs e.g. atropine.

ANESTHESIA FOR NEUROSURGERY**6) Intraoperative Hypothermia:**

- Due to: lengthy operation.
- Treatment: heated blankets, warm i.v. fluids,

7) Special Problems of Posterior Fossa Craniotomies:**a) Brain Stem Injury:**

1. **Injury of vital centers** due to:
 - Direct surgical injury.
 - Retractor pressure.
 - Intraoperative ischemia or edema.

- **Respiratory center** injury causes postoperative;
 - Inability to maintain patent airway.
 - Irregular respiration.

So, spontaneous ventilation may be used by some anesthesiologists to detect intra-operative respiratory injuries.

- **C.V.S center** injury causes changes in BP, heart rate, and rhythm.

2. Injury of Cranial Nerves:

5th, 7th, and 8th cranial nerve injury causes loss of corneal reflexes, lid closure, and hearing defects.

10th cranial nerve injury causes impaired swallowing, aspiration and difficulty to maintain a patent airway.

b) Pneumocephalus:

- It is **air** entering the **subarachnoid space** during surgery especially occurring with the sitting position.
 - Using **N₂O** causes **expansion** of pneumocephalus after dura closure. This compresses the brain resulting in delaying or preventing awakening after anesthesia.
- Therefore, N₂O should be discontinued before the dura is closed. Some authors do not prefer using N₂O at all in sitting craniotomies.

c) Venous Air Embolism:

- The incidence in posterior fossa craniotomy is 20 – 40%.
- "see details in anesthesia with respiratory disease (pulmonary embolism)".

Emergence:

The patients are either;

- a) **Left intubated** + muscle relaxation + CMV + sedation.
- For patients with a severe increase in ICP and brain edema.
- b) **Extubated** at the end of surgery in OR.

Or within 1-2 hours i.e. **Fast-Track Neuro-Anesthesia** for patients without an increase in ICP.

Postoperative Management:

In ICU

For:

- 1) **Close monitoring of**
 - The **neurological** function (early assessment).
 - CVS function as ECG and BP.
 - The **respiratory** function as respiratory depression due to residual effect of anesthetic drugs causes hypercarbia and hypoxia which further increases the ICP.
 - ICP and its management if still high.

2) Postoperative care:

- Patients generally have minimal pain but **postoperative analgesia** is essential.
- Patients lying in **semi-sitting position**.

- Continue moderate fluid restriction and avoid glucose containing solutions.

3) Postoperative Complications:

- 1- **Elective postoperative ventilation** is done in patients with a severe increase in ICP and brain edema with muscle relaxants and sedation.
- 2- **Anticonvulsant therapy** to control seizures e.g. diazepam, or phenytoin.
- 3- Postoperative shivering.
- 4- Psychomotor disturbances.
- 5- Nausea and vomiting.
- 6- IC hematoma.
- 7- Laryngeal swelling due to long standing procedures with extreme head flexion.

Q: Discuss the posterior fossa craniotomy ?

A: It is the same as craniotomy for infra-tentorial lesion.

Q: What is the anesthetic management of the cerebral vascular surgery?

A: It includes;

- IC aneurysm.

- A-V malformation.

- Carotid endarterectomy.

Subarachnoid Hemorrhage

Causes:

- 1) Cerebral aneurysm: 75 – 80%.
- 2) A-V malformation: 4 – 5%.
- 3) Other causes:
 - Trauma.
 - Cocaine abuse.
 - Sickle cell disease.
 - Coagulopathy.

Pathology:

- - Aneurysmal **rupture** causes **leakage** of the arterial blood in the subarachnoid space (and less commonly in the epidural space and brain). This causes a **rapid increase in ICP** which in turn decreases **cerebral perfusion pressure and CBF** leading to loss of consciousness. The fall in CBF decreases the bleeding and stops the subarachnoid hemorrhage.

Clinical Picture:

- 1) **Increased ICP:** It causes **headache** in 85-95% of patients.
 - In unruptured aneurysm due to progressive enlargement.
 - In ruptured aneurysm - Minor bleeding causes mild headache.
 - Severe bleeding causes sudden severe headache.
- 2) **Decreased CBF:** It causes;
 - **Loss of consciousness** for a brief period followed by return of consciousness.
 - **Focal neurologic lesions** which are sensory and motor deficits, cranial nerve palsies and visual disturbances.
- 3) **Blood in Subarachnoid Space:** It causes;
 - **Meningeal irritation** which produces nausea, vomiting, photophobia and nuchal rigidity (symptoms similar to infectious meningitis).
 - **Fever** due to increased metabolic rate (as with head trauma).
- 4) **Cardiovascular Effects of Subarachnoid Hemorrhage:**
 - **Pathology:** Subarachnoid hemorrhage causes **injury of the posterior hypothalamus** which causes release of **norepinephrine** from the adrenal medulla and **cardiac sympathetic efferent**. This increases the afterload and causes direct myocardial toxicity which in turn causes **sub-endocardial ischemia** (pathologic analysis of the myocardium of

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patients who have died acutely from subarachnoid hemorrhage showed microscopic sub-endocardial hemorrhage and myocytolysis).

- **Effects:**

a) **ECG Changes:** in 50-80% of patients with subarachnoid hemorrhage. ST segment depression + T wave inversion: Both are the most common and are scattered and not related to a particular distribution.

b) **Ventricular Dysfunction:** in 30% of patients causing pulmonary edema.

5) Delayed Complications:

a) **Cerebral Vasospasm:** in 30% of patients.

- It occurs usually after 4-10 days pre- and mostly postoperatively.
....."See later postoperative management".

b) **Re-rupture:** in 30% of patients.

- It causes 60% mortality.

c) **Hydrocephalus:** It is either;

- Acute which needs emergency ventricular draining.

- Chronic which needs delayed ventricular shunting.

N.B.; C/P of Arterio-Venous Malformation:

• If it ruptures, it causes IC hemorrhage usually at the age of 10-30 years.

• If it grows, it increases ICP.

• If it is large, it causes high CO failure.

Anesthetic Management:

Preoperative Management:

Preoperative Evaluation:

1) Neurologic Assessment: It should be documented.

For: - C/P as before.....

- Assess for the severity of subarachnoid hemorrhage as before.....

2) Presence of Coexisting Disease:

E.g. hypertension, renal, cardiac or ischemic heart disease. They are **relative contraindications to elective hypotension.**

3) Drug Therapy: for precautions and side effects.

Especially: - β blockers. - Ca^{++} channel blockers.

4) Preoperative Investigation:

Standard +

• CT scan.

• MRI.

• Lumbar puncture- It shows - Blood in CSF.

Preoperative Patient Preparation:

As craniotomy see before.....

+ It is a **bloody operation** so;

a. Multiple large bore venous **cannulas** should be inserted.

b. Intravenous **volume loading** should be done.

c. 4 units of whole **blood** should be available.

Premedications:

As craniotomy see before.....

Intraoperative Management:

Decision to **proceed or delay the surgery** depends on:

1) 50% of patients with subarachnoid hemorrhage have **increased CPK-MB fraction and troponin**. Also, they have **ECG changes** as non-specific T waves, Canyon T waves, ST segment depression, and appearance of U waves. These effects are usually due to extreme hypertension and autonomic discharge which cause myocardial injury which is sub-endocardial. It is **not indicative of trans-mural myocardial infarction**. So; the decision to proceed or postpone the surgery should be weighed against the risk of vasospasm and bleeding. In most cases, the risk of vasospasm and re-bleeding outweighs the risk of perioperative myocardial infarction. Furthermore, if coronary artery disease is present, these patients are not candidates for myocardial revascularization which requires heparinization.

Aim :

Monitoring :

Induction : → as craniotomy see before.....

Position :

Maintenance:

+ **Hyperventilation is avoided** in patients with vasospasm because:

- It decreases CBF which results in brain ischemia.
- With nimodipine (it is used in treatment of vasospasm), there are additive effects with isoflurane causing severe hypotension.

Intraoperative Fluid Management:

- No need for fluid restriction (as other craniotomies), but give the **calculated maintenance amounts**.

- Types and precautions..... "as craniotomy see before".....

Intraoperative Complications and Problems:

1) **Brain Protection:** The same as other craniotomies "mention them in details".....

- + • **Deep hypothermic circulatory arrest:** It needs CP bypass at body temperature (15-28°C) which may be used in:
 - Giant aneurysms.
 - Difficult basilar artery aneurysms.
 - Anatomically complex aneurysms which are not clippable.

2) **Increased ICP:** Its reduction is the same as in other craniotomies "mention them in details".

- + • **Rapid decrease in ICP** before dural opening may promote **re-bleeding** by removing the tamponading effect of ICP on the aneurysm.
- So, mannitol is given after dural opening.

3) **Intraoperative Hypertension**.....

4) **Intraoperative Hypotension**.....

5) **Intraoperative Bradycardia**..... The same as other craniotomies.

6) **Intraoperative Hypothermia**.....

7) **Special Problems of posterior fossa craniotomy**.....

Postoperative Management:

In ICU the same as craniotomy see before.....

ANESTHESIA FOR NEUROSURGERY**+ Postoperative Complications:****(1) Delayed Recovery:****- Causes:****a) Anesthetic:****1- Residual effects of:**

- Inhaled or i.v anesthetics.
- Non-depolarizing muscle relaxants.
- Opioids or benzodiazepines.

2- Hypothermia: It may prolong the effects of i.v anesthetics.**3- Hypoxia, hypercarbia, hyponatremia, or hypoglycemia so, arterial blood gases are needed.****b) Surgical:**

- 1- Subdural hematoma.
- 2- Intra-cerebral hemorrhage.
- 3- Hydrocephalus.
- 4- Pneumocephalus.
- 5- Cerebro-vascular occlusion.

So, CT scan is needed.

(2) Cerebral Vasospasm (Delayed Ischemic Neurologic Deficit**{DIND})****- Definition:**

It is **segmental or diffuse narrowing** of the lumen of one or more intracranial arteries. Its severity is related to the amount and location of subarachnoid blood. Diffuse cerebral vasospasm carries **the worst prognosis**.

- Mechanism: is unknown.

- C/P:

It occurs within **4-10 days** after subarachnoid hemorrhage. Then it resolves by **11-14 days** after subarachnoid hemorrhage.

- Altered level of consciousness (disorientation and drowsiness).
- New onset of focal neurologic deficit.
- Increase in headache, meningism, and fever.
- CVS and respiratory changes if vessels in posterior fossa are involved.

- Investigations:**1- Trans-Cranial Doppler (TCD):****2- Cerebral Angiography:**

- It is the **gold standard** for diagnosis of cerebral vasospasm.

- Management:**A) Prophylaxis:****1) Ca^{++} Channel Blockers:**

- It is the standard prophylactic therapy to prevent cerebral vasospasm.

- Mechanism: is unknown, but may aid in **maintaining cellular integrity** by preventing **Ca^{++} influx into the cells**.

- Agents: **Nimodipine (oral)**
or **nicardipine (i.v.):**

2) Other Measures:

1- **Removal of subarachnoid blood** as quickly as possible.

2- Instillation of **thrombolytic agents** (e.g. urokinase), but this may increase the likelihood of rebleeding.

B) Treatment:

1- Continuation of prophylactic therapy.

2- Hypertension, Hypervolemia, Hemodilution therapy (**HHH therapy**).

= Hypertension, Hypervolemia therapy (H/H R_x).

- **Aim:** To improve CBF to pass the stenotic areas.

- **Technique:** Aggressive hypervolemia and hypertension by;

a) **Intravascular volume expansion** with crystalloids or colloids to increase CO.

- These fluids should be **isotonic** and should contain enough Na⁺ to avoid hyponatremia.

- **Vasopressin or fludrocortisone** may be added to avoid excess fluid and Na⁺ loss.

b) **Vasoactive infusions** e.g. **dopamine and dobutamine** are used if hypervolemia alone is inadequate.

- **Recommended target values:**

- CVP → 10-12 mm Hg.
- PCWP → 15-18 mm Hg.
- Cardiac index → 3-3.5 L/min/m².
- Hematocrit → 30% - 35%.
- ABP → Various target values have been reported, but a reasonable plan is suggested as follows:
 - If the aneurysm is **clipped**, increase systolic BP up to 160-200 mm Hg.
 - If the aneurysm is **unclipped**, increase systolic BP up to 120-150 mm Hg.

- **End point of therapy:** i.e. H/H R_x continue until one of the following;

- Resolution of the neurologic deficit.

Or • Occurrence of complications of therapy as:

- Myocardial ischemia.
- Pulmonary edema (especially with nimodipine as it causes myocardial depression).
- Rebleeding or rupture of a secondary aneurysm.

(3) Increased ICP:

- It is managed as before.

Anesthesia for Head Injury (Head Trauma)**Types:**

1- **Scalp Lacerations:** It causes significant blood loss.

2- **Skull Fractures:** Presence of skull fractures increase the likelihood of a significant intracranial lesion.

a) **Linear Skull Fractures:**

b) **Depressed Skull Fractures:**

c) **Maxillo-facial injury.**

d) **Mandibular Fracture**.....For more details see "Airway Trauma".

3- **Intracranial Injury (Brain Injury):**

a) **Brain contusion, brain lacerations, and traumatic vascular occlusion.**

b) **Epidural Hematoma.**

c) **Subdural Hematoma.**

d) **Intra-Cerebral Hematoma.**

Pathophysiology**A) Primary Brain Injury:**

- It is the **direct result of the disruptive forces** occurring **at the time of impact**. It cannot be treated directly as there is no treatment for the sudden mechanical disruption of brain tissues.

B) Secondary Brain Injury:

- It is the **ischemic brain injury** which occurs **after the initial (primary) trauma** to the brain had occurred.

- Mechanism:

- It is assumed to be **ischemic in origin** due to;
 - Post-injury **hypotension**.
 - **Hypoxemia**.
 - **IC hypertension** due to IC hematoma as subdural, epidural and parenchymal or generalized cerebral edema.
- Contributing mechanisms include;
 - **Cerebral VC** (especially in the first few hours after traumatic brain injury) resulting in a decreased CBF to the threshold for cerebral ischemia i.e. < 18 mL /100 gm brain tissues / min.
 - **Impaired pressure autoregulation** of the cerebral circulation.
 - **Vasogenic brain edema**.

Anesthetic Management:**Preoperative Management:****Preoperative Evaluation and Preparations:****(1) Initial Resuscitation:**

For patients with severe head injury, ideally initial resuscitation should begin in the emergency department.

By ABC protocol**(A and B) Airway and Breathing resuscitation:**

- In severe head injury, there is commonly airway obstruction and hypoventilation resulting in hypoxemia in 70% of patients \pm hypercarbia. This further increases ICP.

- It is managed by;

In severe head injury, **tracheal intubation** is usually needed.

• Special precautions;

a) All patients should be regarded as having **cervical spine injury** (the incidence is 10%) until proved otherwise radiologically. So; **in line stabilization** should be used during airway manipulation to maintain the head in the neutral position.

b) All patients should be regarded as having **full stomach** with a risk of pulmonary aspiration. So; **cricoid pressure** should be maintained during mask ventilation.

• Methods of intubation:

- After adequate preoxygenation with 100% O₂.

- Avoid pressor response of intubation.....see before.

- Induction agents in awake patientsas craniotomy.

- The use of succinylcholine is controversial. Although it is needed for crush induction, but

• It can increase ICP.

• It can produce hyperkalemia.

So; the use of **rocuronium** is a suitable alternative.

- In difficult intubation cases, one of the following can be done;

• Awake intubation.

• Blind nasal intubation.

- Fiberoptic intubation.
- Tracheostomy.
- Blind nasal intubation is contraindicated in patients with;
 - Basilar skull fractures.
 - Maxillofacial injuries.

(C) Circulation resuscitation:

Patients with head injuries may present with **hypotension (hypovolemic shock)** which is more common due to;

- Other associated injuries as thoraco-abdominal injuries.
- Scalp lacerations especially in children.
- Hypotension causes a **marked decrease in CPP** especially if associated with increased ICP resulting in neuronal damage.
- Management:

It should be **managed first** even before neurologic assessment.

Maintaining CPP by normalization of the mean ABP with correction of hypoxia are the main factors in decreasing morbidity and mortality.

a- I.v. fluids:

- Colloids and blood transfusion to maintain Hct > 30%, are preferred than crystalloid solutions in preventing cerebral edema.
- Hypertonic saline (3-7.5%): draws water from the intracellular space so;
 - Restores blood volume in traumatized patient.
 - Decreases brain edema which in turn decreases ICP (effective as mannitol 20 %).

But hypertonic saline cannot be used for long periods due to its side effects.

"See anesthesia with CVS disease (hypovolemic shock)".....

- Avoid hypotonic solutions e.g. lactated ringers and glucose containing solutions.

b- Vasopressors e.g. dopamine

(2) Neurologic Assessment: It should be documented for;

1- Presence of increased ICP and its management as before.....

N.B.; Mannitol: Most head injury protocols call for empiric administration of i.v. mannitol as soon as the patient arrives to the ER. It was thought that mannitol could aggravate the increase in ICP by diffusing through the disrupted BBB and inducing additional cerebral edema.

2 - Assessing the level of consciousness by Glasgow Coma Scale (GCS)

Category	Score
1- Eye opening:	
• Spontaneous.....	4
• To verbal command.....	3
• To pain.....	2
• No response.....	1
2- Best motor response:	
• To verbal command: Obeys.....	6
• To pain - Localize pain.....	5
- Flexion withdrawal.....	4
- Abnormal flexion (Decorticate rigidity).....	3
- Extensor response (Decerebrate rigidity).....	2
- No response.....	1
3- Best verbal response:	
• Oriented & converse.....	5
• Disoriented & converse (confused).....	4
• Inappropriate words.....	3
• Incomprehensible sounds.....	2
• No response.....	1

The highest score is 15 and the lowest score is 3

ANESTHESIA FOR NEUROSURGERY

- Mild head injury —→ GCS 13-15 (80 % of cases).
- Moderate head injury → GCS 9-12 (10 % of cases).
- **Severe head injury** —→ GCS 3-8 (10 % of cases) 35% mortality.

3- Sensory or motor deficits e.g. unilateral non-reactive dilated pupil which indicates an expanding hematoma.

4- Presence of muscle wasting (for hyperkalemia).

5- The Classic Cushing Triad:

Hypertension, bradycardia, and respiratory disturbances are unreliable because they occur late before brain herniation.

(3) Presence of associated injuries (in 10-40%)

E.g. • Intra-abdominal injuries.

- Spine fractures.
- Maxillo-facial and Mandibular trauma.
- Large bone fractures.
- Thoracic injury.....etc

- Presence of associated complications E.g.

- Disseminated intravascular coagulopathy (**DIC**) in severe head injury due to release of large amounts of brain thromboplastin into the circulation.
- Adult respiratory distress syndrome (**ARDS**).
- **Diabetes insipidus**: due to injury of the pituitary stalk.
- **Post-traumatic Seizures (PTS)**.
- **Electrolyte disturbances** as hypo- or hypernatremia, and hypokalemia.

(4) Presence of Coexisting Diseases e.g. hypertension, DM, ischemic heart disease

(5) Drug Therapy.

(6) Preoperative Investigations:

- Critically ill patients should be monitored during investigations and uncooperative patient may need GA.

1- Chest x-ray:

- To detect pulmonary, cardiac, airway, and vascular injuries.
- **If there is any doubt** regarding pulmonary contusions, **a chest tube** should be placed before tension pneumothorax occurs particularly if the patient is going to receive +ve pressure ventilation.

2- Cervical spine x-ray:

- To detect cervical spine injury (sub-laxation, fracture) which requires head stabilization with skull fixation and traction. It should be initiated prior to airway manipulation.

3- CT scan: - For head and neck, thorax, and abdomen.

4- Diagnostic peritoneal lavage.

5- Abdominal ultrasound.

6- ECG: shows

- T wave, ST segment, U wave, QT interval changes and arrhythmias.
- They occur after head injury due to altered autonomic function and may not be associated with cardiac injury.

Premedication:

As craniotomy see before.....

Intraoperative Management

Monitoring:

As craniotomy see before.....+

Induction: as craniotomy "see before" especially avoiding coughing, straining, hypotension, hypercarbia or hypoxia.

Position: as craniotomy "see before".....

Maintenance: as craniotomy "see before".....

Intraoperative Fluid Management: as in resuscitation "see before".....

Intraoperative Complications and Problems: as craniotomy "see before"

Emergence as craniotomy "see before"

Postoperative Management:

As craniotomy "see before".....

+ **Postoperative Complications:** (as preoperative complications).

Anesthesia for Spinal Surgery

Spine surgery includes: - Spinal cord injury.

- Spine (vertebrae) surgery.

They are mainly for decompression of the spinal cord due to:

- Trauma for fixation of a spine (the most common).
- Tumor for resection.
- Degenerative diseases.
- Correction of deformity as scoliosis.
- Protrusion of an inter-vertebral disc for correction (laminectomy or discectomy).
- Infection and abscess drainage.
- Vascular malformation.

Spinal Cord Perfusion:

It is dependent on spinal cord perfusion pressure (it is analogous to the cerebral perfusion pressure).

Spinal cord perfusion pressure =

MAP – spinal cord venous pressure or spinal CSF pressure (whichever is greater).

Anesthetic Management:

Anesthetic Problems:

- 1- Patient position: Supine, prone and sitting with their complications as **air embolism**.
- 2- **Increased blood loss:** So, take its precautions as elective hypotensive anesthesia.
- 3- **Spinal cord protection.**
- 4- **Postoperative blindness.**
- 5- **Problems according to the site of the procedure:**
 - **Cervical spine procedures:**
 - **Difficult intubation:** especially with neck stabilization.
 - **Anterior approach problems:** pneumothorax, and CVS changes.
 - **Postoperative edema** of the brain stem, neck, and airway.
 - **Thoracic spine procedures:** • Thoracotomy and **one lung anesthesia** are needed.
 - **Lumbar Spine procedures:** • **Regional anesthesia** e.g. spinal or epidural can be used.
- 6- **Problems according to the cause:**
 - **Traumatic:** • A, B, and C protocol.
 - Acute spinal cord injury complications.
 - Chronic spinal cord injury complications.
 - Presence of associated injuries.

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- **Ankylosing Spondylitis**.....
- **Rheumatoid Arthritis**..... See "Anesthesia with Musculo-Skeletal Diseases".
- **Kyphoscoliosis**.....
- **Congenital abnormalities as Down's syndrome**.....See "Pediatric Anesthesia".

Preoperative Evaluation and Preparations:**1) Initial resuscitation: ABC Protocol**

(A&B) Airway & Breathing resuscitation: as head injury see before.....Except, there is no increase in ICP if without head injury, so succinylcholine can be used.

(C) Circulation resuscitation:

If hypovolemic shock is associated.

2) Airway Assessment: (Especially in cervical spine surgery).

It should be assessed as the following;

- Assess **difficult intubation** as - Mouth opening for temporo-mandibular joint.
- Mallampati....etc.
- Assess **cervical spine instability:**
 - **Cervical spine mobility and neck movement** should be carefully assessed. Radiology as x-ray, CT, and MRI are needed.
 - **Cervical immobilization:** it is done by one of the following; **cervical collar, axial neck traction, complete halo-vest or halo-body fixation:** these methods causes **difficult intubation.**

3) Neurological Assessment: should be documented.

Assess the **motor and sensory deficits** as a baseline and at frequent intervals especially before and after patient transport and radiology.

4) Spinal Cord Protection (to decrease neurologic injury):

1- The best way to prevent further neurologic injury to the spinal cord is **surgical decompression as soon as possible.**

2- Corticosteroids as **methyl prednisolone:**

It is effective in prevention of further spinal cord injury if given within the first 8 hours after injury 30 mg / kg i.v.

3- **Hypothermia:** some authors advocate local hypothermia to the damaged area of the spinal cord to lessen further neurologic injury.

4- **Ganglioside GM-1:** It helps axonal growth.

5- **NMDA receptor antagonist:** GK-11 is used.

5) Presence of Coexisting Disease e.g. rheumatoid arthritis.**6) Drug Therapy.****7) Preoperative Investigations:**

According to the system affected as;

- Respiratory investigations as pulmonary function tests, AB gases, and chest X-ray (e.g. if there is scoliosis affecting lung function)
- CVS investigations as ECG, X-rays, echocardiography, and catheterization.
- CNS investigations as myelogram, MRI.

8) In Traumatic Spinal Injury:**Presence of Associated Injuries:**

- E.g. tracheal, esophageal, and major vessels injury in penetrating cervical injuries.
- Thoraco-abdominal injuries.....etc.

9) Preoperative Patient Preparation:

1- If intraoperative wake-up test is planned, the patient should be informed and reassured that no pain or discomfort would be felt.

2- Management of any systemic disease that may be associated e.g. respiratory system with scoliosis.....etc.

Premedications:

1) Sedatives:

- Avoid heavy sedation in patients with respiratory impairment to avoid further respiratory depression.

2) Anticholinergics:

- Value: • To treat bradyarrhythmias.
• Antisialagogue.

3) Opioids:

- If patients are in severe pain e.g. degenerative diseases.
- It should be avoided if there is respiratory depression.

4) Protect against aspiration by

- H₂ receptor blockers to decrease GIT secretions.
- Metoclopramide to increase GIT motility.

Intraoperative Management:

Monitoring: Standard +

- **Spinal cord monitoring** (Wake up test, SSEPs, and MEPs).
- Temperature monitoring.
- **Venous air embolism monitoring**.....see before in sitting position.
- Invasive BP especially if controlled hypotensive anesthesia is indicated and to obtain AB gases.
- LV dysfunction monitoring CVP, PAP, and trans-esophageal echocardiography.
- UOP as it is a prolonged operation.

Position: either; **supine, sitting, or prone** position.....consider their complications.

Prone position:

- Technique of prone position: It needs at least 4 personnel to perform it.
- At 1st, **induction** is done in the supine position with a firmly fixed armored tube and placement of invasive monitoring is performed.
- The monitors and the breathing circuits will be **disconnected briefly**.
- Put the arms of patients beside him and turn the patient on OR table over chest rest and iliac crest rest [bolsters] (from parallel rolls or foams) or over special frame aiming to make **the abdomen free** to - Allow proper ventilation.
- Avoid IVC obstruction.
- The patient is turned as **one unit** while the anesthetist supports the head and tube then either turn **head to one side or face down on head rest** (cushinoid holder).
- Put the arms of the patient in a comfortable position with abducted shoulders < 90 degrees and flexed elbows.
- A further bolster should be **placed under the ankle** to prevent forced extension and pressure on the dorsal aspect of the feet.
- **Reconnect** monitor, iv lines, and breathing circuits as soon as possible.

- Complications:

1. **Compression** over the **eyes** (retinal ischemia), **nose** (ischemic necrosis), **knee, genitalia** in ♂ and breasts in ♀ so, take care of them.

2. **Abdominal compression** causes - Impairment of ventilation.
- IVC obstruction which results in epidural vein congestion. This increases blood loss and makes the blood dark in color.

3. CVS: **Postural hypotension** occurs so, some allow light general anesthesia during positioning.

ANESTHESIA FOR NEUROSURGERY

4. **Extreme head rotation** decreases cerebral venous drainage and decreases cerebral blood flow.

Choice of Anesthesia**A) Regional Anesthesia:**

E.g. epidural and spinal anesthesia. they can be used in some cases as discectomy **only in lumbar region**.

B) General Anesthesia:

Induction: if the patient is already not intubated;

Rapid sequence crash induction is done.

- Care for cervical instability.
- Methods of intubation with caring for difficult intubation.

See before..... as awake, fiberoptic, blind nasal, or tracheostomy.

- **Induction agents:**

- Etomidate: It is of choice as it produces minimal CVS effects.
- Thiopentone, or propofol: Avoid large doses as they accentuate hypotension in patients with spinal shock.

- **Succinylcholine:** It can be used safely in the **1st 24 hours** after injury. It is **avoided** after injury in periods **between 1 – 2 days up to 6 – 8 months after injury** to avoid hyperkalemia (K^+ is released from denervated muscle). Succinylcholine is also avoided if malignant hyperthermia is suspected which may be associated with scoliosis.

Maintenance:

O_2/N_2O + Inhalational agent + opioid + muscle relaxants and controlled ventilation or TIVA.

- **Inhalational Agents:**

Sevoflurane and desflurane are preferred than the older agents because they allow **faster recovery** for:

- **Intraoperative wake up technique** to test motor function.
- **Postoperative early neurologic assessment.**

Disadvantages of potent volatile agents:

- They interfere with monitoring of SSEPs and wake-up test.
- They produce dose-dependent myocardial depression.

- **TIVA:** It is suitable because it allows faster recovery especially if SSEPs are monitored.

Intraoperative Problems:

1) **Venous Air Embolism:** especially in sitting position.

2) **Respiratory Dysfunction** especially in traumatic spinal injury:

Due to; - Injury of motor fibers to intercostals or diaphragm (at C3-5 level) in traumatic spinal cord injury.

- Edema of the spinal cord can produce dysfunction several dermatomes above the actual surgical site.

3) **Intraoperative Hypothermia:**

If there is loss of thermal regulation in acute spinal cord injury.

4) **Increased Blood Loss:** - Preoperative autologous donation, hemodilution.

- **Elective hypotension** is needed.
- Wound infiltration by weak epinephrine solution.
- Use RBCs salvage device.
- Elevate the site of the wound e.g. prone position with avoiding increase in the intra-abdominal pressure.

5) Anterior Cervical Approach: Take care of;

- Injury of the trachea, lung (pneumothorax), esophagus, sympathetic chain, carotid sheath or sinus (causing CVS changes).

6) Trans-thoracic Approach:

- It needs thoracotomy and one lung anesthesia.

7) Spinal Cord Protection:

By: - Corticosteroids

- Intentional hypothermia.

Extubation:

Awake extubation with possibility of re-intubation.

Postoperative Management:**Postoperative analgesia:**

Caution are taken with opioids.

Postoperative Complications:**1- Postoperative Edema:** It is either;**a- Brain-stem Edema:**

- It occurs after procedures in the cervical region due to the edema of the cervical cord after surgery which may extend upward along the spinal cord to affect; **the respiratory center** resulting in gradual respiratory insufficiency if the patient

b- Neck and Airway Edema:

- It occurs after procedures in the cervical region.

2- Neurologic Complications: as paraplegia.**Traumatic Spinal Cord Injury:****A) Acute Spinal Cord Injury:**

Trauma is the most common cause of acute spinal cord injury e.g. head trauma, penetrating injury in proximity, crush injuries, etc.

The most common site of injury (C_{5-6} and $T_{12}-L_1$).

Physiologic Sequelae of Acute Spinal Cord Injury:

It depends on the level of the lesion. High lesions produce the most severe damage;

1) Respiratory:**a- Respiratory Impairment due to:**

• **Intercostal muscle paralysis**, if the lesion is at C_5 (the diaphragm is intact). These patients have a vital capacity around 25% of the normal resulting in respiratory impairment especially on exercise or stress.

• **Diaphragmatic paralysis**, if the lesion is above C_3 (the diaphragm is innervated by the phrenic nerve C_3-C_5). This causes abolishing the diaphragmatic ventilation and making artificial ventilation mandatory.

b- Paralysis of intercostal and abdominal muscles creates **ineffective cough** and decrease **chest wall compliance** with tidal volume at or near the closing capacity with tendency of airway closure. This causes retention of secretions, atelectasis, V/Q mismatching, and intrapulmonary shunting.

2) Cardiovascular:**a- Spinal Shock (Neurogenic Shock):**

Loss of • Sympathetic outflow i.e. sympathectomy causes hypotension and bradycardia.

• Spinal reflexes.

• Sensation.

• Motor power (i.e. flaccid paralysis).

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These losses last from **hours to days, to even weeks (typically 1-3 weeks)** then reflexes, muscle spasm, and sympathetic over-activity gradually return.

N.B.; Compensatory tachycardia is not seen because sympathetic reflexes are not present (the only autonomic reflex present is the vagal reflex which can produce dangerous levels of bradycardia).

b- Brady-dysrhythmias:

- They range from sinus bradycardia to profound brady-dysrhythmias up to cardiac arrest which can occur any time from hours to days after injury. It is enhanced by hypoxia.

c- Left Ventricular Dysfunction:

- It can occur even in young, previously healthy individuals.

- Due to decreased sympathetic outflow and increased vagal tone. This causes depression of myocardial contractility, so on increased circulatory blood volume, pulmonary edema can occur easily.

3) Autonomic:**a- Loss of Thermal Regulation:**

- So that, body temperature will equilibrate with room temperature (Poikilothermy) causing either; • Hypothermia especially in the air-conditioned ICU or it may mask a febrile response.

Or • Hyperthermia.

b- GIT:

- Gastric atony, dilatation, hyper-secretion and ileus are common which increase the risk of aspiration.

c- Bladder Dysfunction.**4) Sensory and Motor Deficits:**

- Lesions • Above C₇, T₁ cause **quadriplegia**.

• Above L₄ cause **paraplegia**.

B) Chronic Spinal Cord Injury**Physiologic sequelae:**

The same as acute spinal cord injury.....+

1) Respiratory:

1. **Pulmonary emboli** due to immobility.

2. **Pulmonary infections and upper airway obstruction** due to inability to cough and clear secretions.

3. **Dyspnea** due to airway hyperactivity.

4. Some patients need **partial ventilatory support and diaphragmatic pacing**.

2) Autonomic: It appears after resolution of spinal shock.

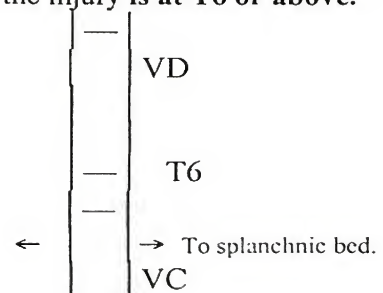
Autonomic Hyper-reflexia (Mass Reflex)

Due to loss of normal descending inhibitory impulses so, cutaneous or visceral stimulation below the level of injury can produce intense autonomic reflexes if the injury is at **T6 or above**.

- **Bowel or bladder stimulation** causes

• **Severe VC** below the spinal cord lesion resulting in severe life threatening hypertension (leading to cerebral hemorrhage and myocardial infarction) + Reflex bradycardia.

• **Severe VD** above the spinal cord lesion Resulting in facial flushing, sweating, headache, blurred vision, seizures, cerebral hemorrhage, dysrhythmias, and hypothermia.



- This syndrome is not observed in spinal cord lesions below the dermatome T₇-T₁₀ because the splanchnic bed is still innervated and able to vasodilate. Therefore, this prevents hypertension from developing.

- Treatment;:

1. Immediate withdrawal of the initial reflex trigger is of choice.
2. Vasodilators and sympathetic blockers to treat hypertension.
3. Good deep general anesthesia or regional anesthesia can prevent this reflex.

3) Electrolyte Imbalance:

1) **Hypercalcemia** due to immobilization resulting in;

- Dysrhythmia.
- Renal stones and infections which lead to renal failure.

2) **Acute hyperkalemia** from 1 -2 days up to 6 – 8 months after injury by succinylcholine.

4) Decubitus Ulcers (Bed Sore):

It easily progresses to systemic sepsis and septicemia.

5) Pancreatitis and Cholecystitis are common.

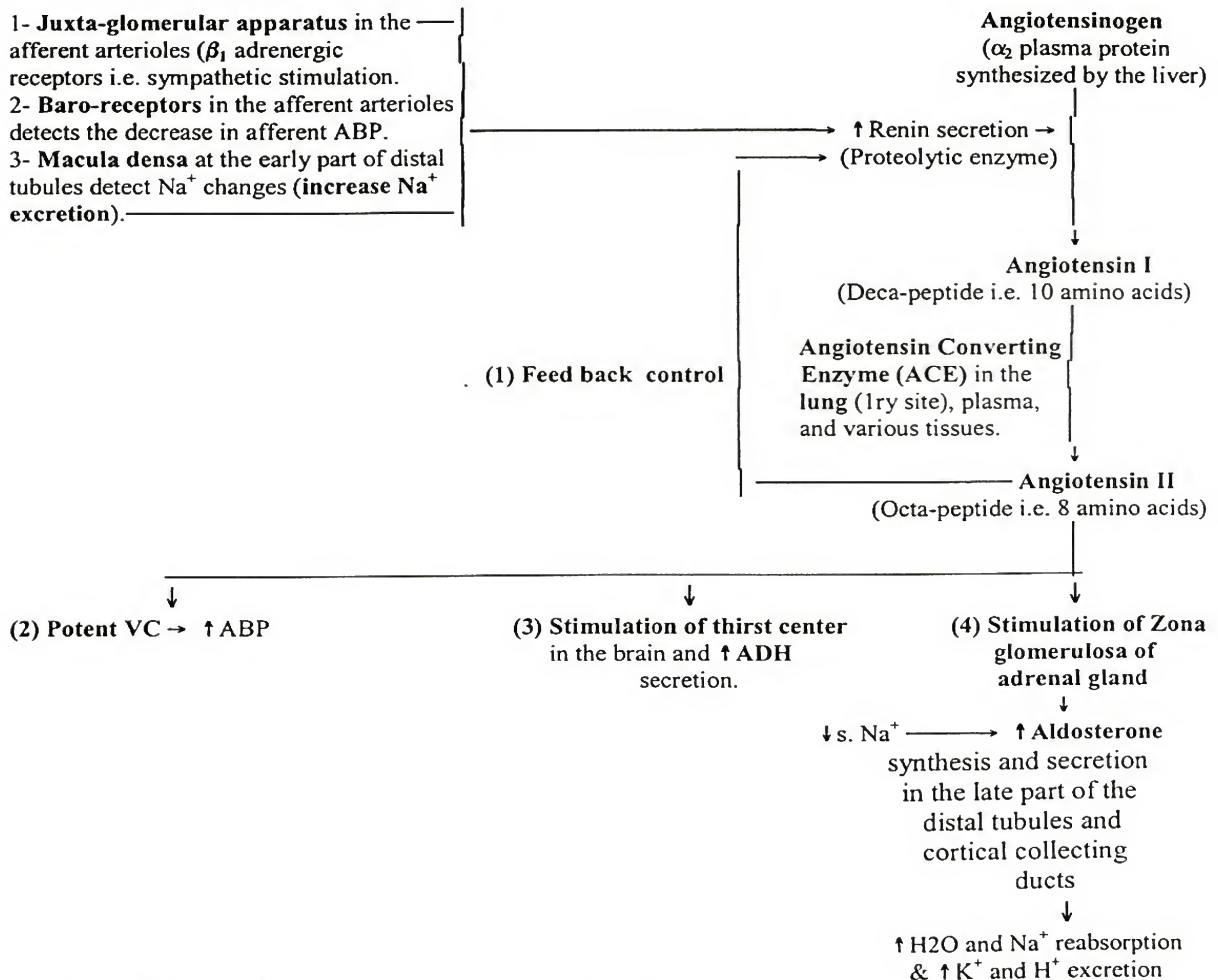
6) Chronic Pain:

It is also called; phantom pain, neuropathic pain, and dysesthetic pain.

CHAPTER 12

ANESTHESIA WITH RENAL DISEASES

Renin Angiotensin System



Evaluation of Renal Function

A) Blood Tests:

1- Blood Urea Nitrogen (BUN):

- Normal values = $10 - 20 \text{ mg / dL} = 1.6 - 3.3 \text{ mmol / L}$.

- BUN decreases in → - Starvation.

- Liver diseases.

increases in → - Decreased GFR.

- Increased protein catabolism e.g. sepsis, trauma, blood degradation in GIT or in hematoma or high protein diet.

- CHF and dehydration increases urea (but not creatinine).

2) Serum Urea:

- Normal value = 20 – 40 mg / dL = 2.7 – 7.0 mmol / L.

3) Serum Creatinine:

- Normal value = 0.6 – 1.3 mg / dL = 0.045 – 0.12 mmol / L = 45 – 120 nmol / L.

- S. creatinine is derived non-enzymatically from creatine which is a product of muscle metabolism.

- Because the body muscle mass is usually fairly constant s. creatinine measurements are generally reliable indices of GFR.

- S. creatinine increases in;

- Decreased GFR.
- Large meat meals.

4) Serum Osmolality:

- Normal value = 280 – 300 mosmol / kg.

B) Clearance Tests:**1) Inulin Clearance:**

- It equals GFR normal value = 100 – 150 mL / min.

2) Para-Amino-hippuric Acid Clearance:

- It equals renal plasma flow. Normal value = 560 – 830 (600) mL / min.

3) Creatinine Clearance:

- It equals GFR. Normal value = 100 – 120 mL / min.

- It is calculated by;

$$\bullet \text{ Creatinine clearance} = \frac{[\text{Creatinine}] \text{ Urine} \times \text{Urinary flow}}{[\text{Creatinine}] \text{ Plasma}} \quad \text{mL/min}$$

It needs accurate urine collection over a specified period of time. Two hours are enough. (24 hours urine collection is not necessary nowadays by modern techniques).

$$\bullet \text{ Creatinine clearance} = \frac{(140 - \text{Age}) \times \text{Lean BW in Kg}}{72 \times [\text{Creatinine}] \text{ Plasma}} \quad \text{mL / min}$$

For ♀, this equation is multiplied by 0.85 to compensate for a smaller muscle mass.

- It is a very reliable test in assessing kidney function. Patients are divided into:

- Normal → 100-120 ml / min.
- ↓ Renal reserve → 60-100 ml / min.
- Mild renal impairment → 40-60 ml / min.
- Moderate renal impairment (renal insufficiency) → 25-40 ml / min.
- Renal failure (RF) → < 25 ml / min.
- End stage renal disease (chronic RF) → 10 ml / min.

C) BUN: Creatinine Ratio:

- Normal BUN: creatinine ratio = 10:1

- Decreased renal tubular flow rates increase urea absorption, but do not affect creatinine

So; this increases the ratio to > 10:1 as in;

- Volume depletion (prerenal).
- Edematous disorders associated with decreased tubular flow e.g. CHF, cirrhosis, nephrotic syndrome.
- Obstructive uropathies.
- Increased protein catabolism.

Differentiation between oliguria causes:

U = Urine P = Plasma	Normal value	Prerenal causes e.g. dehydration	Renal Failure (Acute tubular necrosis) Early Late
a- Plasma: - Urea : creatinine ratio	10 : 1	> 20 : 1	< 10 : 1

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b- Urine:			
- Specific gravity	1000 - 1040	> 1022	1010 - 1012
- Osmolality mosmol/kg	300-1200	> 400	< 350
- Urine sediment	N	Normal or hyaline cast	Tubular or granular cast
c- U/P ratio			
- U/P Urea ratio	> 20 : 1	> 20 : 1	< 14 : 1 < 5 : 1
- U/P Creatinine ratio		> 40 : 1	< 10 : 1
- Fe Na		< 1	> 1
-Renal failure index		< 1	> 1

N.B.; - **Functional excretion of Na % (FeNa)** = $\frac{\text{Na clearance}}{\text{Creatinine clearance}} = \frac{U_{\text{Na}} / P_{\text{Na}}}{U_{\text{cr}} / P_{\text{cr}}}$

$$\text{- Renal failure index} = \frac{U_{\text{Na}}}{U_{\text{cr}} / P_{\text{cr}}}$$

Both are the most sensitive tests.

In **prerenal failure**, Na^+ is reabsorbed avidly from glomerular filtrate to restore intravascular volume, but in **renal failure**, it does not occur due to epithelial injury. Creatinine is reabsorbed less efficiently in both cases.

Anesthesia for Patient with Renal Impairment or Failure (RF)

Acute Renal Failure

Definition:

A rapid deterioration in renal function causes retention of nitrogenous waste products (azotemia) which include urea, guanidine compounds (as creatine, creatinine)...etc. If it is not treated, irreversible acute renal failure occurs.

Causes: (Causes of Perioperative Oliguria)

a) **Pre-renal Causes (Ischemia):** I.e. acute decrease in renal perfusion.

- Hypovolemia.
- Hypotension i.e. decreased MAP below the limits of renal autoregulation (< 80 mm Hg).
- Low CO e.g. CHF.

b) **Renal Causes:** Acute tubular necrosis is the most common cause.

- All causes of prerenal ischemia if severe and prolonged.
- Nephrotoxins:
 - Endotoxins:
 - Hb from mismatched blood transfusion.
 - Porphyria.
 - Gram – ve septicemia.
 - Bilirubin in obstructive jaundice.
 - Exotoxins:
 - Antibiotics as sulphonamide or garamycin.
 - Heavy metals: mercury or phenol.

c) **Post-renal Causes:**

- Urinary tract obstruction (bilateral).
 - E.g. • Compression of bladder by retractors during surgery.
 - Ligation of both ureters during surgery.
 - Bilateral stone in ureters.
- + • Extravasation (only in perioperative oliguria).
 - E.g. • Bladder rupture or unintentional cystotomy.
 - Severing both ureters.

C/P: It is either;

- **Anuric RF** i.e. No UOP. It occurs in post-renal causes.
- **Oliguric RF** i.e. UOP is < 400 mL/day (< 0.5 mL/kg/hr). It is the most common.

It lasts usually for **2 weeks** and then is followed by the diuretic phase with progressive increase in UOP then renal functions improve over several weeks up to 1 year.

- **Non-oliguric RF** i.e. UOP is > 400 mL/day. It is the least severe form.

Differentiation between causes:

- Post-renal causes produces anuric RF.
- pre - and renal causes..... "see before".

Chronic Renal Failure (Uremia)

Definition:

Progressive and irreversible decrease in renal functions over the course of at least **3-6 months**.

Causes:

- 1) Hypertensive nephron-sclerosis.
- 2) Diabetic nephropathy.
- 3) Chronic glomerulo-nephritis.
- 4) Polycystic renal disease.
- 5) Others pyelonephritis, lupus erythromatosis, vasculitis, and congenital anomalies.

C/P: It is seen when GFR (creatinine clearance) becomes < 25 mL/min (if it 25-40 mL/min it is renal impairment not failure).

1) CNS:

- Peripheral neuropathy mainly sensory in lower limbs.
- Autonomic neuropathy.
- Muscle twitching.
- Encephalopathy: astrexis, myoclonus, lethargy, confusion, seizures, and coma.

2) CVS:

- Fluid overload causing CHF. This causes peripheral and pulmonary edema.
- Hypertension due to - Decreased Juxta-glomerular apparatus perfusion. This increases renin level.
 - Fluid overload.
- Arrhythmias.
- Conduction block due to Ca^{++} deposits in the conductive system.
- Pericarditis.
- Accelerated atherosclerosis due to hyper-lipidemia.
- Hyperdynamic circulation (high CO HF) due to - Anemia.
 - A – V shunt of the dialysis.

3) Pulmonary system:

- Acidosis resulting in hyperventilation.
- Alveolar and interstitial edema resulting in hypoxia.
- Pleural effusion.

4) GIT:

- Anorexia, nausea, vomiting, and under-nutrition.
- Delayed gastric emptying due to autonomic neuropathy.
- Hyperacidity which may lead to ulceration and GIT bleeding.
- Adynamic ileus.

5) Endocrinal system:

- Glucose intolerance due to peripheral resistance to insulin.
- Hyper-triglyceridemia resulting in atherosclerosis.
- 2ry hyper-parathyroidism which causes hyper-phosphatemia and vitamin D depletion. These cause bone resorption and decreased Ca^{++} absorption which causes bone disease.

6) Skeletal:

- Osteo-dystrophy due to increased PTH which causes bone resorption.
- Peri-articular calcifications due to Ca^{++} deposition 2ry to hyper-phosphatemia.

7) Metabolic:

- Metabolic acidosis due to nonvolatile acid accumulation.

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- Hyperkalemia (hypokalemia may occur if the patient with diuresis).
- Hyponatremia (hyponatremia may occur if pyelonephritis, analgesic nephropathy, vomiting, diarrhea or diuretics).
- Hyper-magnesemia especially if the patient is taking Mg containing antacids.
- Hyper-uricemia.
- Hyper-phosphatemia.
- Hypocalcemia due to:
 - Ca^{++} deposition peri-articularly by hyper-phosphatemia.
 - Decreased Ca^{++} absorption from the gut due to the decrease in renal synthesis of 1,25 dihydroxy cholecalciferol (vitamin D).
- Hypo-albuminemia.

8) Hematologic:

- Normo-chromic anemia (usually 5-7 gm %) due to:
 - Decreased erythropoietin production resulting in decreased RBCs production.
 - Decreased RBC survival.
 - BM suppression due to repeated infections.
 - GIT bleeding.
 - Hemodilution.
- WBC dysfunction: It increases susceptibility to infections.
- Platelet dysfunction: It increases the bleeding time due to decreased endothelial release of VW's factor and factor VIII.

9) Skin:

- Hyper-pigmentation.
- Ecchymosis.
- Pruritis.

Q: Discuss ICU management of renal failure?

A: Mention the management of acute and chronic renal failure.

Preoperative Management**Preoperative Evaluation and Preparation****1) Preoperative Dialysis:** (In anesthetic management of renal failure)

- The ideal time of dialysis is on the day of surgery or the previous day.

- Indications of dialysis:

- 1- Laboratory:
 - Creatinine clearance $< 5 \text{ mL/min}$.
 - S. creatinine $> 10 \text{ mg/dL}$.
 - S. urea $> 200 \text{ mg/dL}$.
 - S. K^+ $> 7 \text{ mEq/L}$.
 - S. bicarbonate $< 12 \text{ mEq/L}$.

- 2- Deterioration of C/P: as
 - Fluid overload.

- Pericarditis.
- Refractory GIT symptoms.
- Metabolic encephalopathy.
- Coagulopathy.
- Drug toxicity.

- Avoid fluid overload or hypovolemia after dialysis. The patient's weight pre - and post-dialysis should be compared.

- Repeat s. electrolytes, BUN, and s. creatinine to assess the adequacy of dialysis.

2) Preoperative Detection and Management of Complications (and C/P) of RF:**1- CVS:**

- Proper management of CHF, hypertension, arrhythmias, and heart block.
- Echocardiography to detect pericardial effusion and aspiration.
- ECG shows arrhythmias, heart block, and ischemia.

2- Pulmonary System:

- Arterial blood gases to detect hypoxemia.
- Chest x-ray to detect pleural effusion, pericardial effusion, infection or pulmonary edema.

3- GIT:

- Preoperative fasting and proper premedication as there is an increased liability for aspiration.

- 4- **Endocrine:**
 - S. glucose is done to detect hyperglycemia.

5- Skeletal:

- Careful patient positioning as the patient is liable for bone fractures.

6- Metabolic: • ABG_s to detect metabolic acidosis.

- S. electrolytes to detect electrolyte disturbances.

7- Hematologic:

- Preoperative packed RBC transfusion or erythropoietin transfusion (side effect is hypertension).

If: - Severely anemic patients (Hb < 6 – 7 gm/dL).

- Significant intraoperative blood loss is expected.

- Bleeding time and coagulation studies:

Increased bleeding time indicates platelet dysfunction treated by:

1. Cryoprecipitate 10 units as it contains VWF and VIII.

Or 2. Desmo-pressin infusion 0.3 – 0.4 mg/kg i.v. over 30 min. It is the non-vasoconstrictive analogue of vasopressin. It stimulates endothelial release of VWF-VIII (the peak action is 1-4 hours and duration 4- 8 hours).

8- Treatment of any infection e.g. chest infection etc.**Premedication:**

1) **Sedatives:** Doses should be decreased.

2) **Anticholinergics:**

- Atropine and glycopyrrolate: They are safe in premedication doses, but on repeated administration, accumulation of their active metabolites occur.

3) **Aspiration Prophylaxis:** Doses should be decreased.

- H₂ blockers: They are excreted mainly by the kidney so, decrease their doses.

- Metoclopramide: It is used to accelerate gastric emptying 10 mg orally or slowly i.v. It is partially excreted by the kidney.

Intraoperative Management:**Monitoring:**

Standard: +

- BP (Cuff or intra-arterial catheter) measurement is avoided in the arm with the A-V fistula.
- Invasive ABP, CVP, and PCWP in expected major fluid shifts.

Choice of Anesthesia:**A) Regional Anesthesia:**

- It is **preferred** in minor surgeries e.g. to establish A-V fistula for dialysis e.g. by brachial plexus block for the upper limb because it causes VD and abolishes VC.
- Care for **coagulopathy** as it is a relative contraindication.

B) General Anesthesia:**Induction:**

Rapid sequence crash induction with cricoid pressure.

- Due to nausea, vomiting, GIT bleeding, increased gastric acidity, and delayed gastric emptying. All these can increase the risk of aspiration.
- I.v. cannulas should be placed in the arm opposite to that of the A-V fistula.
- Induction agents:

- Thiopentone: **Decrease the dose** to 2-3 mg/kg or only a sleeping dose.

Due to: Hypo-albuminemia which decreases protein binding and results in increased free drug.

Acidosis which increase the non-ionized fraction of drug. This increases drug entry to the brain.

N.B.; **Ketamine is avoided:**

Due to: - Its hypertensive action in hypertensive renal patients.

- Its active metabolites which will accumulate.

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- **Decrease the hypertensive (pressor) response to intubation**....."see before airway management".

- **Succinylcholine** 1.5 mg/kg.

It is used safely if s. K^+ is < 5 mEq/L at the time of induction (suxamethonium increases s. K^+ up to 0.6 mEq/L). If s. K^+ is higher or is doubtful, use non-depolarizing muscle relaxants instead.

Maintenance:

$O_2 \pm N_2O$ + volatile agents + opioids + muscle relaxant + controlled ventilation.

• **N_2O :**

- It is used cautiously or not used at all in - Patients with poor ventricular function.
- Severely anemic patients (Hb < 7 gm/dL) to allow the use of 100% O_2 .

• **Volatile agents:**

- Volatile agents **are ideal** for patients with renal failure as:

- They do not depend on the kidney for elimination.
- They can control ABP.
- They have minimal effects on renal blood flow.

- In chronic renal failure, patients with severe anemia patients (Hb < 5 g./dL), there is an accelerated induction and emergence due to:

- Decreased blood: gas partition coefficient.
- Decreased minimal alveolar concentration (MAC).

- **Isoflurane is the drug of choice** as it is with the least effects on CO.

Halothane is used safely.

Enflurane is a poor choice (used cautiously) as it increases fluoride levels theoretically.

Methoxyflurane is contraindicated as it increases fluoride ion level markedly causing nephro-toxic effects.

Sevoflurane is used with some precautions, as it must be used with fresh gas flow more than one L/min.

• **Opioids:**

- **Fentanyl, sufentanil and alfentanil** are of **choice** as they are metabolized in the liver to **inactive metabolites**.

- Morphine and pethidine: They are used in small doses or better avoided as they are metabolized in the liver to active metabolites which may accumulate in renal impairment.

• **Muscle Relaxants:**

- Atracurium, cis- atracurium and mivacurium are of choice as they are not excreted by the kidney.

- Rocuronium and vecuronium are used safely as only a small % of them are excreted by the kidney.

- D- tubocurarine, pancuronium, and pipecuronium are used cautiously with NM monitoring as a large % of them are excreted by the kidney.

- Metocurine, alcuronium, gallamine, and doxacurium are avoided as they are mainly excreted by the kidney.

• **Controlled Ventilation:** is of **choice** because:

- It **prevents respiratory acidosis** which could occur with spontaneous ventilation under anesthesia. Spontaneous ventilation increases the preexisting metabolic acidosis resulting in severe CVS depression and increased s. K^+ .

• **Reversal of Muscle Relaxants:**

- Edrophonium, neostigmine, and pyridostigmine are mainly eliminated by the kidney so, their half lives in patients with renal impairment are prolonged at least as much as any of the above muscle relaxants. So, recurarization is not expected.

- Pyridostigmine is more preferred than neostigmine due to its longer duration.

- Glycopyrrolate is more preferred than atropine.

due to: - Its longer duration.

- Its less anti-muscarinic effects.

So, it is suitable in patients with hypertension or coronary artery disease.

Intraoperative Fluid Management:

Judicious fluid therapy is needed to;

- Avoid volume depletion which may cause postoperative renal failure if there is only renal impairment.

- Avoid volume overload which may cause postoperative pulmonary edema.

Type:

- Avoid glucose containing solutions: due to the associated glucose intolerance.

- Avoid K^+ containing solutions as ringer or lactated ringer in patients with hyperkalemia so, the use of **normal saline** is of choice.

- **Packed RBCs** are used to replace blood loss.

Postoperative Management:

Close observation is needed to detect:

1) **Postoperative Renal Failure:** (in renal impairment).

It results in postoperative oliguria.

- Cause: It occurs in patients with renal insufficiency i.e. creatinine clearance 25-40 mL/min especially with sepsis, after major surgery or trauma, when they are exposed to volume depletion intraoperatively.

- Treatment: (= **Renal protection**):

1. **Adequate Hydration:**

The only proven therapy is the prevention and early treatment of acute renal failure by adequate fluid resuscitation titrated against;

• Maintenance of CO (cardiac index 4.5 L/min/m²).

• Maintenance of MAP (80 mm Hg).

• PCWP and CVP.

N.B.; Problems of over-hydration e.g. pulmonary edema and congestion are easier to be treated than problems of under-hydration e.g. acute renal failure and DVT.

2- **Avoid Hypotension:** which is associated with anesthesia.

As it decreases renal perfusion resulting in acute renal failure.

3- **Maintain UOP:** (after adequate hydration) by:

- Osmotic diuresis: **mannitol** 0.25 – 0.5 gm/kg over 15 min repeated once if there is no response.

- Loop diuretics: **furosemide** bolus 1-3 mg/kg i.v. or infusion both are of doubtful value

- **Dopamine** infusion 2-5 µg/kg/min to increase RBF via activation of vasodilatory dopaminergic receptors in renal vasculature.

2) **Postoperative Apnea and Hypoxia (Recurarization):**

- It should be early detected and managed.

3) **Postoperative Hypertension ± Pulmonary Edema:**

- Vasodilators + diuretics.

- Hemo-dialysis is a useful treatment.

Perioperative Oliguria

Definition: UOP is < 0.5 mL/kg/hr.

Causes:

(1) **Incorrect catheter placement** (as in the vagina in ♀ or the urethra in ♂), **kinking or disconnection** from the reservoir tubing are the **most common** causes intraoperatively.

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(2) In abdominal or pelvic surgery:

- **Compression** of the bladder by a retractor.
- **Unintentional cystotomy.**
- **Ligation or severing of one or both ureters.**
- **Trendelenburg (head down) position.**

(3) All causes of **acute renal failure.**

Management: It is directed to the possible cause.

(1) 1st, **assess the integrity of the urinary catheter.**

(2) Notify the surgeon to check - Position of retractors.

- The ureters and urinary bladder.

(3) Administer a fluid volume challenge (500 mL NS)

↓
If no response assess CVP

↓
Low

So; it needs more fluid therapy

↓
Normal or high

↓	↓	↓	↓
* PCWP < 15 mm Hg * UOP Low * Cardiac index < 4.5 L/min/m ²	• PCWP > 15 mm Hg * UOP Low * Cardiac index < 4.5 L/min/m ²	• PCWP > 15 mm Hg * UOP Low • Cardiac index > 4.5 L/min/m ²	• PCWP > 15-20 mmHg • UOP high • Cardiac index > 4.5 L/min/m ²
Need more fluid therapy	Cardiogenic shock needs - Inotropes (if ABP is low) - Vasodilators (if ABP is high) - Selective pulmonary VD (if there is pulmonary hypertension) as PGI ₂ or NO. - Intraortic balloon pump.	It is either; • High cardiac output shock: It needs vasopressor if it is with decreased ABP or • Bad kidney function: It needs i.v. mannitol, furosemide, dopamine or hemodialysis if it is with increased ABP.	Hypervolemia So stop or decrease the rate of infusion.

CHAPTER 13

ANESTHESIA FOR GENITO-URINARY SURGERY

The Transurethral Resection of the Prostate (TURP)

Anesthetic Problems:

1. Type of patients.
2. Lithotomy position.
3. Hemorrhage.
4. TURP syndrome.
5. Hypothermia.
6. Bladder perforation.
7. Coagulopathy.
8. Postoperative pain.
9. Postoperative septicemia.

Preoperative Management:

- **Type of Patients:** Patients are **elderly** males with coexisting cardiac, pulmonary, and renal diseases (due to long standing urinary obstruction).
- **Cross-matched Blood** should be available for:
 - Anemic patients.
 - Large prostate > 30 – 40 gm.

Intraoperative Management:

Patient Position: Lithotomy position.

- It is the 2nd most common used position, after supine position (figure 13-1).
- Preoperatively: It is important to ensure that;
 - 1- No limitation of movement of these joints especially if there is osteo-arthritis which is common in the older patients.
 - 2- Pre-existing lumbar back pain may be worsened by extended periods of this position. So; small lumbar support may be used to maintain the lumbar lordosis.
- During positioning:
 - Two personnel are required to safely move the patient's legs simultaneously up or down to avoid stressing the spinal ligaments.
 - The assistants pull the patient down the table before elevating the legs.
- So, - The anesthetist should support the patient's head carefully and ensure that there is sufficient slack in the hoses of the breathing system to avoid accidental extubation or disconnection.
 - The arms should be supported as they may fall from the table when the patient is moved.
- The strap supports should be padded and the legs should hang freely within the straps.

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- The sacrum should be supported.

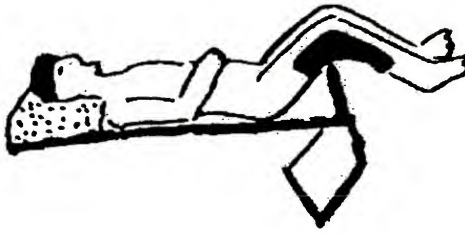


Figure 13-1; Lithotomy position

- Risks of Lithotomy Position:

1- Iatrogenic Injuries:

- Injury of the **common peroneal nerve** (causing loss of dorsi-flexion of the foot) due to compression by the strap supports against the head of the fibula.
- Injury of the **saphenous nerve** (causing numbness along the medial calf) due to medial aspect of the leg resting on strap support.
- Injury of the **obturator or femoral nerves** due to excessive flexion of the thigh against the groin.

2- Respiratory Effects:

- It decreases vital capacity and FRC because abdominal contents restrict the movement of the diaphragm especially in the obese and elderly resulting in atelectasis and hypoxia which are accentuated by the head-down (trendelenburg) position.
- So, O₂ saturation monitoring is essential.

3- C.V.S Effects:

- Leg elevation increases venous return acutely (adds about 600 mL blood to the central circulation). This precipitates or exacerbates congestive heart failure in a compromised heart.
- Also, rapid leg lowering decreases the venous return acutely resulting in hypotension and decreasing CO especially with general anesthesia or regional anesthesia. So, ABP monitoring is essential and the body position must be changed gradually.

Monitoring:

Standard: +

- **Mental status** monitoring in awake patients is the best monitor for detection of early signs of TURP syndrome and bladder perforation.
- **Temperature:** to detect hypothermia.
- **Clinical signs of hyper - or hypovolemia.**

Choice of Anesthesia:

A) Spinal or Epidural Anesthesia: They need T₁₀ sensory level block.

- It is of choice because:
 - It decreases surgical blood loss by reducing ABP during surgery.
 - It produces VD which results in peripheral pooling of blood. This decreases the **severity of the circulatory overload.**
 - It allows **early diagnosis of TURP syndrome** or bladder perforation in awake patients.
 - It decreases the incidence of **postoperative venous thrombosis.**
 - It allows postoperative analgesia.

- Precautions:

- **Avoid large i.v. fluid preload** which may increase the risk of TURP syndrome.
- If hypotension occurs due to the block, it is better treated by vasopressors e.g. **ephedrine** than by i.v. fluids.
- In patients with cancer especially those with back pain, consider the possibility of **vertebral metastasis** as it is a contraindication of regional anesthesia.

B) General Anesthesia:

Best by intubation and controlled ventilation.

- Avoid high airway pressures as they may increase bleeding from the prostatic bed.
- TURP syndrome may delay or prevent emergence from GA.

Intraoperative Fluid Management:

- Amount: give **minimal amounts** to avoid circulatory overload.
- Types: - **Na containing crystalloids** to decrease the risk of hyponatremia.
 - If blood transfusion is needed, give packed RBCs.

Intraoperative Complications:

1) TURP Syndrome:

- **Causes:** **Systemic absorption** of the irrigating fluid (especially if water is used) via:
 - The opened extensive network of **venous sinuses** in the prostate.
 - Fluid accumulates in the peri-prostatic and retro-peritoneal space if the prostate capsule is violated (opened) during surgery.

- **Factors increasing the incidence of TURP syndrome:**

The amounts of irrigating solution absorbed are increased by:

- 1) **Prolongation of the duration of resection:** > 150 min. This increases morbidity and mortality (usually 45-60 min).
- 2) **Increase in the hydrostatic pressure of the irrigation fluid** determined by the height of irrigation fluid: so, after 60 -70 cm H₂O pressure (at 60-70 cm height above the patient), there is a marked increase in the absorption of irrigation fluids.
- 3) **Decrease in the venous pressure of the prostate.**
- 4) **Increase in the number and size of venous sinuses** opened during surgery determined by the size of the gland. Also violation of the capsule during surgery increases fluid absorption.
- 5) **The bad surgical technique.**
- 6) **Excessively distended bladder** during surgery.

- **Average Amount Absorbed:**

- It is **20 mL / min**. It is usually 1-1.5 L, but may be increased up to 5-8 liters.
- Volume absorbed = $\frac{\text{Preoperative s. Na}^+}{\text{Postoperative s. Na}^+} \times \text{ECF} - \text{ECF}$.

Provided that ECF is 20 – 30 % of body weight in kg.

E.g.: 60 kg patient with preoperative s. Na⁺ 140 mEq/L and postoperative Na⁺ (or Na⁺ at the time of assessment) 100 mEq/ L. So; $140/100 \text{ ECF} - \text{ECF} = 1.4 \text{ ECF} - \text{ECF} = 0.4 \text{ ECF} = 0.4 \times 60 \times 20 \% = 4.8 \text{ liters}$.

- **Types of Solutions Used:**

a) Isotonic or Near Isotonic (Slight Hypotonic) Non-Electrolyte Irrigating Solutions:

- Glycine 1.2 % and 1.5 % (288 mosm/L).
- Cytal (mixture of sorbitol 2.7% and mannitol 0.54%) (195 mosm/L).
- Mannitol 3%.
- Sorbitol 3.3%.
- Dextrose (glucose) 2.5-4%.

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- Urea 1%.

b) **Distilled Water:**

- It is not used now because;
- It is an extremely hypotonic solution causing **hemolysis**.
- On significant absorption, **acute H₂O intoxication** occurs.

N.B.; Electrolyte solutions are avoided (not used) for irrigation in TURP because they can conduct the electrical current from the electrocautery (Resectoscope) to the surrounding tissues causing burns.

- **Clinical Picture:**

- It can appear **intra-** or **postoperatively** (from a few minutes after the onset of surgery up to hours after the end of surgery).
- In **awake patients**, the 1st symptoms are:
Difficult breathing, headache, nausea, vomiting, dizziness or confusion.
- In **anesthetized patients**, the 1st symptoms are:
Increased ABP (then hypotension), decreased HR, increased airway pressure or delayed recovery from anesthesia.

a) **Dilutional Hyponatremia:** (with any solution)

C/P appears when s. Na⁺ reaches < 120 mEq / L.

- **Irreversible brain damage** cause, loss of alpha wave + irregular discharge of high amplitude slow wave activity on EEG.

Actually, these CNS effects are not related to the degree of the fall of s. Na⁺, but to the rate (speed) of fall of s. Na⁺ as more rapid fall in s. Na⁺ results in increased CNS effects.

• **ECG changes:**

- At 120 mEq / L → possible widening of QRS complex.
- At 115 mEq / L → widened QRS, elevated ST segment, inverted T wave, U wave
- At 110 mEq / L → PVCs, ventricular tachycardia & VF.
- At 100 mEq / L → cardiac arrest.

- **Altered renal function** causing decreased postoperative UOP.

- It may prolong the non-depolarizing muscle relaxants.

b) **Fluid Overload:** (with any solution)

- Congestive HF.
- Pulmonary edema.

Both cause dyspnea, cyanosis, and arrhythmias which result in angina.

- Increased ABP (then hypotension occurs).

c) **Hypo-osmolality (Acute Water Intoxication):** (if distilled water is used)

- **Cerebral edema** causes headache, restlessness, confusion, seizures, increased ICP, decerebrate posture, dilated sluggish reactive pupils up to coma lasting from a few minutes up to days.

• **Hypotension and bradycardia.**

- Acute intravascular **hemolysis** causes sudden prostrations, chills, clammy skin tight chest, bronchospasm, increased s. K⁺ (causing VF). Free Hb which reaches the renal tubules result in renal failure and shock.

d) **Solute Toxicity:**1- **Hyper-glycinemia:** (Glycine toxicity)

- Due to increased s. glycine > 1000 mg / L (normal = 13 – 17 mg/L).
- Glycine is an inhibitory neuro-transmitter so its toxicity results in;
- CNS toxicity (inhibition).
- CVS toxicity i.e. decreased CO (depression).

- Eye toxicity i.e. blurring of vision, haloes around objects, transient blindness which gradually resolve within 8- 48 hours after surgery (due to the toxic effect of glycine on the retina).

- **Hyper-ammonemia:** (very rare)

- Due to increased s. ammonia $> 500 \mu\text{mol/L}$ (normal = $5-15 \mu\text{mol/L}$) because ammonia is derived from glycine degradation.

- It produces CNS toxicity as nausea, vomiting, and coma which resolve when the ammonia levels becomes $< 150 \mu\text{mol/L}$.

- It is suggested that **arginine deficiency** predisposes to CNS toxicity after absorption of glycine solution because the arginine is an intermediate in the conversion of ammonia to urea in the ornithine cycle in the liver. Therefore, addition of arginine or ornithine to glycine irrigating solutions may protect against hyper-ammonemia and so CNS toxicity.

2- **Hyperglycemia:**

- Due to increased sorbitol or dextrose especially in diabetic patients.

Management of TURP Syndrome:

A) **Prophylactic:**

1- Preoperative correction of heart failure, fluid and electrolyte imbalances.

2- Avoid factors which increase the incidence of TURP syndrome e.g. decrease the duration of the resection, do not elevate fluid height $> 60 \text{ cm}$, good surgical techniques, void the bladder, and maintain ABP.

B) **Therapeutic:**

- **Early detection** is very important so, when TURP syndrome is suspected:

1. **Notify the surgeon** to discontinue surgery as soon as possible.

2. **Fluid restriction** by slowing i.v. fluids.

3. Recheck s. electrolytes, Hb concentration and arterial blood gases.

- Once diagnosis is established;

1) **Diuretics** are given to eliminate the absorbed water e.g. furosemide 20 mg i.v or mannitol i.v .

2) **Oxygen** mask or nasal cannula application to eliminate hypoxia.

3) Treatment of symptomatic **hyponatremia** ($\text{s Na}^+ < 120 \text{ mEq/L}$).

- In mild cases: normal saline 0.9% is infused till s. Na^+ approaches the normal level.

- In severe cases: hypertonic saline (3% or 5%) is used.

- It should be given at a rate $< 100 \text{ mL/hr}$ to avoid circulatory fluid overload.

- It should be corrected at a rate $< 0.5 \text{ mEq/L/hour}$ (i.e. $< 12 \text{ mEq/L/day}$) as rapid correction causes central pontine myelinolysis.

300 mL of hypertonic saline can usually correct the hyponatremia.

4) Treatment of **Seizures** by:

- Midazolam $2 - 10 \text{ mg i.v}$.

- Diazepam $5 - 20 \text{ mg i.v}$.

- Thiopentone $50-100 \text{ mg}$.

- Phenytoin $10 -20 \text{ mg/kg}$.

5) If **pulmonary or cerebral edema** occur, they are treated by:

- **ICU admission and invasive monitoring** as invasive BP, CVP, and PAP.

- **ETT for mechanical ventilation** and to prevent aspiration in deteriorated level of consciousness.

- **Dehydrating measures.**

2) Increased Blood Loss (Hemorrhage):

- Generally, blood loss is related to the surgical experience, the duration of the procedure, and the size of the prostate.

- In TURP, blood loss is increased due to associated coagulopathies.....see later.

ANESTHESIA FOR GENITOURINARY SURGERY

- Blood loss is **often difficult to assess** because the blood is heavily diluted by the irrigating fluid and an inexperienced anesthetist often underestimates the total losses. Therefore, the anesthetists **should depend on clinical signs**.

3) Intraoperative Hypothermia:

- Irrigation solutions given at room temperature decrease the body temperature 1°C per hour resulting in hypothermia which occurs in 5% of patients.
 - Therefore, irrigating solutions should be warmed to body temperature.

4) Coagulopathy:

- Causes:

1. **DIC** due to the release of thromboplastin from the prostate into the circulation.
2. **Dilutional thrombocytopenia** as a part of TURP syndrome.
3. **Release of fibrinolytic agents** (plasminogen and urokinase) from the mucosa of the lower urinary tract.

5) Bladder Perforation:

- Causes:

- Resectoscope.
 - Over-distension of the bladder with the irrigating fluid.
- Diagnosis is confirmed by: Cysto-urethrography.
 - Treatment: Immediate supra-pubic cystotomy.

Postoperative Management:**1) Postoperative Analgesia:**

- It is mandatory due to;
- Old age.
 - Presence of urinary catheter that irritates the raw prostatic bed.
- By: opioids (decrease the dose in elderly) or by the epidural route.

2) Postoperative Septicemia:

- Because opening of the venous sinuses allow entry of organisms into the blood stream. This causes septicemia up to septic shock which usually lasts for a few hours and then the patient recovers from it.
 - So, prophylactic antibiotics (commonly gentamicin) are given preoperatively.

3) Continuous Bladder Irrigation:

- To prevent blood clotting in the catheter.
 - The fluid used for irrigation should be;
- Warmed to avoid postoperative hypothermia and shivering as this may dislodge the clots resulting in increased postoperative bleeding.
 - It is checked regularly for its volume to ensure that large amounts are not being absorbed.

Q: What are possible causes of hypotension during TURP?

In any organ transplantation the following subjects must be discussed:

1- Indications.

2- The recipient: • Severe C/P of the organ failure.
 • No contraindications are present.

3- The donor: • Living-related.
 • Cadaveric or brain-dead.

4- Anesthetic Management:

- Complete asepsis should be present.
- Anesthetic management of the failed organ.

- Immuno-suppression (pre-, intra, and postoperative).
- Postoperative Management:
 - ICU admission.
 - Pain.
 - Complications:
 - Organ failure and its assessment.
 - Rejection - Super-acute (intraoperative).
 - Acute (hours to weeks).
 - Chronic (months to years).
 - Vascular occlusion
 - Leak e.g. ureter or bile duct..
 - Infection.
- Hemorrhage.

Renal Transplantation

Indications: End stage renal failuresee causes.

Contraindications:

A) Absolute Contraindications:

- Reversible renal impairment.
- Ability of conservative measures to maintain a useful life.
- Advanced forms of major extra-renal complications (cerebro-vascular or coronary disease, or neoplasia).
- Active infection.
- Active glomerulonephritis.
- Previous sensitization to donor tissues.

B) Relative Contraindications:

- Age > 60 to 65 years.
- Presence of vesical or urethral abnormalities.
- Ilio-femoral occlusive disease.
- Psychiatric problems.
- Oxalosis.

Anesthetic Management:

Anesthetic Problems:

- 1) The Transplanted Kidney.
- 2) The recipient is a patient with end stage renal failure with its anesthetic problems.
- 3) Immuno-suppression for the recipient.
- 4) Complete precautions against infections.
- 5) The graft preparation and anastomosis.
- 6) The graft adequacy.
- 7) Problems of clamp release.
- 8) Intraoperative fluid management.
- 9) Postoperative complications.

The Transplanted Kidney (Donor Graft)

- There must be matching of both - Human Leukocyte Antigen (HLA).
 - ABO groups.
- It is either;

a) A Cadaveric Graft:

Current organ preservation techniques allow ample time (24-48 hours) to preserve a cadaveric kidney at low temperature. So, allowing ample time for preoperative recipient preparation e.g. dialysis.

ANESTHESIA FOR GENITOURINARY SURGERY**Or b) Living Related Graft:**

The donor should be completely healthy.

Living related transplants are performed electively with the donor and recipient anesthetized simultaneously, but in separate rooms.

Preoperative Management:**1) Preoperative Patient Evaluation, Preparation and Premedication:**

First correct the recipient's medical conditionsame as before

Especially • s. K^+ should be < 5.5 mEq/L

• Coagulopathy should be corrected.

2) Immuno-Suppressive Therapy Protocol:

- It consists of corticosteroids, cyclosporine, azathioprine, tacrolimus, and calcium channel blockers.

3) Complete Aseptic Precautions Against Infection:

Due to the immunosuppressant effects.

E.g. use sterile disposable anesthetic circuit.

Intraoperative Management:**Choice of Anesthesia:**

• Regional Anesthesia (spinal or epidural):

It can be used.

• General Anesthesia:

It is commonly used.

Monitoring:

Standard +

• CVP for fluid balance to allow adequate hydration and avoid fluid overload.

• UOP may indicate the adequacy of the graft.

• S. electrolyte for K^+ .

Intraoperative Complications:

1) The same anesthetic management for patients with chronic renal failure.

2) The graft preparation and anastomosis:

- The transplant is carried out by placing the donor kidney retro-peritoneally.

• **In living-related grafts:** After removal of the kidney from the donor, it is flushed immediately with iced ringer lactate solution containing heparin and mannitol allowing ischemic time to be between 20-30 min.

• **In cadaveric grafts:** Before release of the arterial clamp and after completion of the anastomosis, an intra-arterial injection of verapamil 10 mg is given by a direct push into the kidney.

- Furosemide 200 mg is given for both grafts immediately after completion the anastomosis.

3) Problems of release of the vascular clamp:

After completion of the arterial anastomosis, the vascular clamp is released resulting in;

• **Hyperkalemia** due to K^+ release which was contained in the preservative solutions or from the lower limbs (if external iliac vessels were clamped). This may cause sudden cardiac arrest.

• **Hypotension** due to distribution of blood to lower limbs.

• **Transient metabolic acidosis** due to reperfusion of ischemic legs.

• **Hypertension** due to;

- Release of renin from the donor kidney.

- Release of catecholamines from the intact adrenal gland of the donor kidney, so, it should be excised.

4) Adequacy of the graft:

- A **brisk UOP** usually occurs after arterial anastomosis which indicates **good graft function** (this diuresis may resemble non-oliguric renal failure).
- If an **oliguric phase** precedes the diuretic phase this indicates **prolonged graft ischemic time**. So, fluid therapy must be adjusted appropriately and mannitol 0.25-0.5 gm/kg should be given.
- If **sudden increase in body temperature** after transplantation occurs, this indicates **super-acute rejection** (the graft is needed to be removed).

Fluid Therapy:**- Amount:**

- **Adequate** fluid volume should be given because patients tend to be hypovolemic to avoid postoperative renal failure.
- The cadaveric kidney requires higher plasma volume and higher ABP to initiate diuresis than the normal kidney. So, keep the systolic BP around 130-160 mm Hg and the CVP around 10-15 cm H₂O.
- Anuric patients typically need 8 mL/kg/day to replace the insensible water loss (in adults, it is 500-600 mL).

- Type: • 5% albumin or normal saline.

- Half normal saline is preferred by some anesthetists to decrease the Na⁺ load on the new kidney.
 - Avoid K⁺ containing solutions:
- Blood transfusion is indicated in severe blood loss or Hct < 15% by **packed washed RBCs** (leukocyte-poor blood) to avoid rejection because introduction of leukocytic antigen can cause production of additional antibodies predisposing to rejection of a subsequently implanted kidney.

Postoperative Management:

Most patients are extubated postoperatively.

+ **Anesthetic Management of Chronic RF**.....

+ **Postoperative Complications:**

1) **Acute renal failure** (acute tubular necrosis) in the transplanted kidney due to prolonged ischemia or cyclosporine toxicity. It is treated by hemodialysis.

2) **Renal artery occlusion.**

3) **Hyper-acute or delayed rejection.**

C/P: fever, decreased UOP, increased s. creatinine, renal enlargement and tenderness similar to pyelonephritis or recurrent glomerulopathy. They can be differentiated by renal biopsy.

It is treated by corticosteroids and anti-lymphocyte globulins.

4) **Graft rupture.**

5) **Urinary fistula.**

6) **Wound infection or other infections** due to chronic immunosuppression.

7) **Lymphoceles.**

8) **Increased incidence of cancer** due to chronic immuno-suppression.

CHAPTER 14**ANESTHESIA FOR
ORTHOPEDIC SURGERY****General Anesthetic Problems:****1) Type of the Patient:**

1. The patients are usually elderly so, with;

- **Coexisting diseases** as CVS, respiratory, diabetic.....which need preoperative preparative detection and management.
- **Arthritic diseases** as osteoarthritis, rheumatoid arthritis which need special precautionssee later (musculo-skeletal).

2. The patients may be poly-traumatized so, **other associated injuries** may be present.

2) Increased Blood Loss:

It is either;

1. Preoperative:

- Especially in hip and femur fracture. See later.
- It should be replaced before anesthesia.

2. Intraoperative:

- **Factors increasing bleeding:**

- 1- Aspirin therapy for arthritic diseases.
- 2- Surgical techniques and experience.
- 3- Previous surgeries e.g. hip surgery.
- 4- Presence of femoral neoplasm or Paget's disease.
- 5- Hypercapnia and hypoxia.

- **Factors decreasing bleeding:**

- 1- **Tourniquet** e.g. knee surgery.
- 2- **Controlled hypotension.**

3- **Epidural and spinal anesthesia:** There is less blood loss than GA in spite of maintaining similar MAP, the reason for this is uncertain, but may include differences in the resulting vasodilatation of the venous and arterial vascular system. This causes redistribution of blood flow.

4- Intraoperative **blood salvage** and preoperative **autologous blood donation.**

3. Postoperative:

- Careful monitoring and replacement of blood loss.

3) Increased Incidence of DVT:

- The incidence is increased because they are elderly patients, with prolonged immobilization or with circulatory occlusions so, prophylactic measurements should be taken.

4) Increased Incidence of Fat Embolism:

.....See before anesthesia with respiratory diseases (pulmonary embolism).

5) Patient Position: is either; supine, lateral, or prone position.

6) Complete Aseptic Conditions:

- Especially for arthroplasty (hip or knee replacement).
- The surgery may be done under a laminar flow hood with the anesthesiologist and equipment outside the boundary.
- Prophylactic antibiotics should be given. The anesthesiologist should check that.

7) Intraoperative Radiology:

- Wearing a lead apron (which doubles the distance from the source and decreases the dose 4 folds) and turning away at moments of exposure to decrease thyroid and lens damage are advised.
- Intraoperative fluoroscopy and arthroscopy may need darkness in the O.R.

8) Postoperative Analgesia:

- It is mandatory because early mobilization is an important factor for decreasing morbidity, but avoid excessive sedation in elderly age.

Choice of Anesthesia:**A) Regional Anesthesia:** E.g. spinal or epidural for surgeries.

It is more preferred + light i.v. sedation.

- Advantages:

1. Little effects on C.V.S and respiratory system.
2. It decreases blood loss "see above".
3. It decreases the risk of aspiration.
4. It decreases the risk of DVT because;
 - It allows greater lower limb venous blood flow due to sympathectomy.
 - It decreases platelet activity.
 - It attenuates the postoperative increase in factor VIII and VW factor.
 - LAs have an anti-inflammatory action.
 - It attenuates the postoperative decrease in anti-thrombin III.
 - It changes stress hormone release.
5. It allows postoperative analgesia for rehabilitation.

B) General Anesthesia:**1) I.v. Agents only:** by single dose.

For short procedures as manipulation of a stiff joint or closed reduction.

2) Controlled Ventilation + Muscle Relaxants:

For long and complex procedures especially with abnormal patient positions.

N.B.; Some combine regional block with light GA e.g. epidural block + light GA for hip surgeries to get the advantages of both.

Hip Surgery

I) Fracture Neck Femur:**Anesthetic Problems:**

The same as above (1) to (8) +

(1) Type of Patient:

- Patients are usually with severe pain on moving the limb.
- So; • They may need good premedications (but in small doses due to old age).
- Anesthesia may be induced while the patients are still on their bed (which is brought to the operating room).

(2) Blood Loss:

- Generally, the amount of blood loss from hip fractures depend on the location of the fracture: They are arranged in order from the least to the most bleeding fracture (figure 14-1). The fracture is one of the following;

- Subcapital.....Intracapsular fractures (because the capsule acts as a tourniquet).
- Transcervical.....Intracapsular fractures (because the capsule acts as a tourniquet).
- Base of neck.....Extracapsular fractures.
- Intertrochanteric.....Extracapsular fractures.

ANESTHESIA FOR ORTHOPEDIC SURGERY

- Subtrochanteric.....Extracapsular fractures.

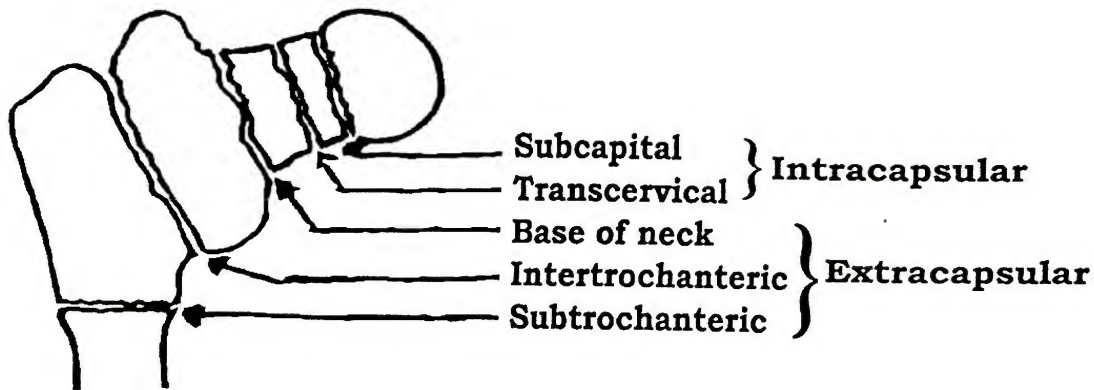


Figure 14-1; Fracture Neck of femur

Choice of Anesthesia:

The same as above..... +

- **Para-median approach** is more suitable in elderly patients (in spinal or epidural) as;
 - It avoids the frequently calcified interspinous ligaments.
 - It can be performed without optimum flexion of the patient.

- **Hypobaric local anesthetics:**

They can be used as they allow easier positioning because the patient does not have to lie on the fractured hip.

II) Total Hip Replacement (Arthroplasty)Anesthetic Problems:

The same as above (1) to (8) +

9) Paget's Disease of Bone:

- It is usually present in candidates for total hip replacement.
- It causes hyperemia of the bone leading to **arterio-venous anastomosis**. This results in low peripheral resistance and **high CO failure**.

10) Bone Cement Implantation Syndrome:

- Cause:

Acrylic bone cement (methyl methacrylate cement)

- It is used to fix the artificial joint component in place (Thompson prosthesis).
- It consists of 2 components a liquid and a powder both are mixed together before use. This reaction liberates heat i.e. exothermic reaction and forms a doughy polymer.
- Its use may cause bone cement implantation syndrome due to one of the following causes:
 - 1- **A reaction to the heat generated** when the cement sets. It may cause **air embolism**.
 - 2- **Toxic or vasodilator effects** (and tachycardia) of free liquid monomers absorbed into the circulation.
 - 3- **Cement Anaphylaxis**.
 - 4- **Autonomic Effects** try to the pressure rise within the femoral shaft.
 - 5- **Embolism from the medullary cavity** (air, polymer particles, or fat as 'it is fat solvent' due to resultant intra-medullary hypertension > 500 mm Hg).
 - 6- Release of **tissue thromboplastin** may trigger platelet aggregation leading to micro-thrombus formation in the lung. This in turn causes;

- CV instability due to circulation of vasoactive substances.
- VC of pulmonary vessels and bronchioles resulting in V/Q mismatch and hypoxia.
- C/P:

1- Hypotension, decreased CO and circulatory collapse up to cardiac arrest.

2- Hypoxemia and pulmonary hypertension.

They occur at the time of insertion of the cement into the medullary cavity of the femur and impaction of the stem of the femoral head prosthesis, occurring within **30-60 sec up to 10 min** after insertion.

- Precautions; to avoid it:

1- Stop N₂O and increase inspired O₂ concentration **before cementing**, this decreases the size of air emboli if they occurs.

2- Delay insertion of the cement **for 2 min after mixing** so that it has a stiffer consistency with the presence of less free monomers.

3- Observe the patients carefully for the C/P during insertion.

4- Monitor the patients adequately by;

- **Invasive ABP.**

- **CVP** for proper fluid and blood replacement. So, avoid hypovolemia at the time of insertion of the prosthesis.

- **Monitors for air embolism** e.g. precordial or esophageal stethoscope.

- **Pulmonary artery pressure monitor**; pulmonary embolization increases pulmonary vascular resistance (PVR) which increases pulmonary artery pressure (PA) without change in pulmonary capillary wedge pressure (PCWP). It also decreases CO.

5- Perform high pressure lavage of the femoral shaft to remove debris (potential micro-emboli).

6- Perform venting of the medullary cavity to decrease the pressure effect. This pressure is produced by the piston effect of impaction of the prosthesis's stem into the cement filled medullary cavity. This is best done before inserting the cement and the prosthesis by; -

Drilling the bone cortex.

- Passing a catheter down the shaft.

Knee Surgery

I) Knee Arthroscopy:

Anesthetic Problems:

The same as above (1) to (8) +

9) Tourniquet..... "See below".

10) Outpatient Anesthesia (avoid heavy opioids).

- Early postoperative ambulation is required with good pain relief by;

- **Intra-articular bupivacaine** 20-30 mL of 0.25% with 1: 200 000 epinephrine is usually used ± Morphine 1-5 mg. This causes prolonged analgesia for several hours.

The exact mechanism is controversial. It may be due to the presence of peripheral opioid receptors in the joints.

- **3 in one lumbar plexus block.**

(Lateral femoral cutaneous, obturator, and femoral nerve).

II) Total Knee Joint Replacement:

Anesthetic Problems:

The same as above (1) to (8) +

ANESTHESIA FOR ORTHOPEDIC SURGERY

9) Bone Cement Implantation Syndrome....."as above", but cement is very rarely used.

10) Tourniquet (also in upper limb surgery).

- Technique:

- Pneumatic type is used; it should be **padded especially in thin patients**.
- The limb should be **elevated for about 1 min**, then elastic exsanguinations by **Esmarch bandage** is used prior to the tourniquet, but **not in cases of fractures, sepsis, sickle cell anemia, and neoplasm**.
- The **best sites** are the **midpoint of the thigh** (for lower limb) and the **upper arm** (for upper limb) as they are with the greatest muscle bulk, thus avoiding nerve injury.
- Pressure used in - Upper limb: 50 mm Hg above systolic BP (**up to 300 mm Hg**) for 1 hour.
- Lower limb: 100 mm Hg above systolic BP (**up to 500 mm Hg**) for 1.5-2 hours.
- Reperfusion after 1-2 hours of inflation is not universally recommended as some believe it supplies more substrates for free radical production without prolonging safe inflation time.

- Disadvantages:

- 1- Tourniquet of **both lower limbs** increases **CVP and ABP** which may cause serious effects in patients with compromised cardiac function especially in infants and elderly patients. So bilateral lower limb tourniquet should be avoided.
- 2- Soft tissue, nerve or vascular **damage**, or severe bruising may occur with prolonged or incorrect application.
- 3- Increased incidence of **DVT** in the lower limb.
- 4- **Tourniquet pain**: severe aching and burning pain which may increase ABP about 1/2- 1 hour after cuff inflation depending on many factors.
- * Anesthetic techniques: I.v. regional > epidural > spinal > G.A.
- * The intensity and level of block.
- * Choice of local anesthetic: hyperbaric spinal with tetracaine > isobaric bupivacaine.
- 5- **On release of the tourniquet**, the following can occur;
 - **Reactive hyperemia** which causes **hemorrhage** especially if improper hemostasis.
 - **Shift of the blood to the periphery** which causes a temporary **decrease in ABP and increase in HR**.
 - Release of **acids (and K⁺)** produced by anaerobic metabolism into the circulation results in increased PaCO₂.

It rarely causes C/P except if bilateral lower limb tourniquets are used.

- Contraindications:

- 1- **Peripheral vascular disease**.
- 2- **Sickle cell** disease or trait, but it can be safely used in them after particular attention to maintain oxygenation, normo- or hypocarbia, hydration, and normothermia.

N.B.; If non-depolarizing muscle relaxants are used in a patient with a tourniquet, avoid drugs such as atracurium which degrade spontaneously. Once the preliminary dose has worn off, a further bolus (although effectively paralyzing the rest of the patient) will have no effect on the isolated limb which will continue to move throughout the procedure, embarrassing the surgeon and anesthetist alike. So use drugs which need liver or kidney clearance. It should be injected before the tourniquet application.

CHAPTER 15

ANESTHESIA FOR E.N.T. SURGERY

Tonsillectomy ± Adenoidectomy

Anesthetic Problems:

- 1- Type of patients: Pediatric (\pm Upper respiratory tract infection).
- 2- Day case anesthesia.
- 3- Airway management.
- 4- Blood loss especially in young age.

Preoperative Management:

- **Type of Patients:** Patients are usually young and healthy, but may be with;
- **Acute upper respiratory tract infection (URTI):** so, **postpone surgery for 2 weeks** even after recovery because URTI causes hyperactive airway reflexes.
- Precautions for **day-case Anesthesia** if used "see later".

Premedications:

1. **Sedatives:** e.g. diazepam 0.3 mg/kg oral syrup.
 - There are usually needed as patients are young children.
 - They should be avoided in obstructive sleep apnea syndrome.
2. **Anticholinergics:** e.g. atropine 0.02 mg/kg oral syrup.
 - They are usually needed to decrease salivation.
 - They are better avoided in hot weather.

Intraoperative Management:

Induction: It is either by;

1- I.v. agents (via i.v. cannula inserted first by using EMLA cream).

Or 2- Inhalation agents (then i.v. cannula is inserted).

Large tonsil may lead to respiratory obstruction which makes it difficult to maintain the airway. In case of obstructive sleep apnea, -ve pressure pulmonary edema may occur.

Intubation:

Orally, by reinforced ETT to decrease the risk of kinking by self-retaining mouth gag.

Or preformed (RAE tube) to direct the breathing circuit away from the surgery site.

- By • Deep inhalation anesthesia to facilitate intubation.

Or • Suxamethonium (premedication with atropine is essential).

- Blood loss: It is usually mild intraoperatively.

In children **weighting < 15 Kg** (3-4 years old), blood loss is considered large so, **loss of 100 mL blood** in them may **need blood transfusion**.

Extubation:

Awake extubation in the lateral position with slight head down should be done after suctioning and ensuring that the pharynx is free from blood.

Postoperative Management:

- 1- The patient should be positioned prone with the head turned to one side (**tonsillectomy position**) to allow drainage of any residual oozing out of the mouth and to allow early detection of postoperative bleeding tonsils.
- 2- Postoperative analgesia e.g. rectal paracetamol should be given at the end of surgery.
- 3- In obstructive sleep apnea, ICU is needed for close observation.

Postoperative Bleeding Tonsil

Anesthetic Problems:

- 1- Shocked Patients.
- 2- Full stomach.
- 3- Blocked nose by the blood.
- 4- Postoperative laryngeal edema (due to intubation).

Preoperative Management:

1. The patient is usually hypovolemic with orthostatic hypotension, tachycardia, pallor, sweating, restless, up to altered state of consciousness.
So, preoperative resuscitation is very important by crystalloids or blood otherwise severe circulatory collapse occurs with induction.
2. The patient has a stomach full with blood which increases the risk of aspiration so, preoperative evacuation of the stomach by a large bore naso-gastric tube is important.
3. Preoperative Hb, Hct, cross-matched blood and coagulation study are done.

Intraoperative Management:

- The patient is placed head down in a lateral position and the suction apparatus should be positioned within grasp before induction.
- Good preoxygenation is essential.
- Induction: **Rapid sequence crash induction + cricoid pressure**
- By: • Small dose thiopentone 3-4 mg/kg.
- Or • Etomidate or ketamine if there is any doubt about proper preoperative resuscitation.
- Intubation: by
 - Succinylcholine 1-2 mg/kg or rocuronium are of choice.
- Or • Some do deep inhalational induction to facilitate intubation.
- **Cuffed oral ETT** (due to presence of blood in the nose) not cuffed in children < 10 years old.
- Before awakening, re-evacuate the stomach by a large bore naso-gastric tube
- Extubation: Awake in the lateral position.

Postoperative Management:

Laryngeal edema may occur due to re-intubation so; - Dexamethazone i.v.
and -. Humidified O₂.

Larynx **Endoscopy**

It includes:

1. Laryngoscopy (diagnostic or operative).
2. Micro-laryngoscopy.
3. Esophagoscopy.
4. Bronchoscopy.

Anesthetic Problems:

1. Patients with upper airway problems.
2. It is usually done as an outpatient procedure.
3. Profound muscle relaxation is needed.
4. Oxygenation and ventilation.
5. C.V.S. instability.
6. Postoperative laryngeal spasm or edema.
7. Laser precautions.

Preoperative Management:

Careful preoperative assessment for potential airway problems e.g. foreign body aspiration, tracheal stenosis, obstructing tumors.

- By history, examination and investigations as CT scan or MRI
- If the patient is suspected difficult intubation, 1st secure the airway before induction of anesthesia e.g. by fiberoptic bronchoscope, awake intubations or by tracheostomy under LA.
- All equipment for **difficult intubation** should be available preoperatively.

Premedication:

- Sedatives: are avoided if any degree of airway obstruction is suspected.
- Anticholinergics: are used to decrease secretions and avoid bradycardia.

Intraoperative Management:

It may be an outpatient procedure so, consider its precautions.

1. Profound Muscle Relaxation:

- It is done usually by short acting non-depolarizing muscle relaxants (as it is usually a short procedure) to provide masseter relaxation for introduction of the suspension laryngoscope.
- In children, spontaneous ventilation without muscle relaxant may be used.

2. Oxygenation and Ventilation:**1- Micro-Laryngeal Tracheal Tube (MLT tube) or Mallinckrodt Critical Care Tube:**

- It is the most commonly used. It can be used orally or nasally.
- It is 4, 5, or 6 mm I.D, but with the same adult length (31 cm) and with a large high volume low pressure cuff (filled with 10 mL) and is stiffer (less prone to compression).
- Advantages:
 - o Its small size will not impede the surgeon's view.
 - o Its cuff will prevent aspiration of blood or debris.
 - o It allows introduction of inhalational agents.
 - o It allows monitoring of ET CO₂.

2) Conventional E.T.T. of Small Size:

- Use one size smaller in children.
- Use size 4, 5 or 6 mm I.D in adults.
- Disadvantages:

It is **too short for the adult trachea.**

It is with low volume cuff that will exert high pressure against the trachea.

3) Pollard's Tracheal Tube:

- It is formed from latex reinforced with a nylon spiral.
- Its proximal end size is 10 mm ID and its distal end size is 5-7 mm ID.

In (1), (2), and (3):

- Induction: - Thiopentone + suxamethonium or short acting non-depolarizing muscle relaxant.
 - ± - Spraying the vocal cord with 3 mL lidocaine 4% or painting with cocaine 3% to assist smooth anesthesia and decrease the risk of post-extubation laryngospasm.

- Maintenance: O₂ and N₂O + Volatile agents + Controlled ventilation.

4) Insufflation of High Flow of O₂ via a small catheter placed in the trachea.

Patients breathe spontaneously.

5) Intermittent – Apnea Technique:

- The ventilation and anesthesia are maintained with O₂ and a potent volatile agent by a face mask or E.T.T. for periods which alternate with periods of apnea during which the surgery is performed, usually 2-3 min.

ANESTHESIA FOR E.N.T. SURGERY

- Pulse oximeter is essential.
- There is a risk of hypoventilation and aspiration.

6) Manual Jet Ventilation:

- It is connected to a side port of the laryngoscope (Saunders jet injector, introduced by Saunders in 1967).
- During inspiration (1-2 seconds), the jet pressure increases gradually until adequate chest rise and fall is noted.

While the O₂ source is directed through the glottic opening, it entrains room air into the lung (Venturi effect).

- Expiration is allowed passively in (4-6 seconds).
- It is important to monitor the chest wall motion constantly for proper tidal volume assessment and to allow sufficient time for exhalation to avoid air trapping (figure 15-1).

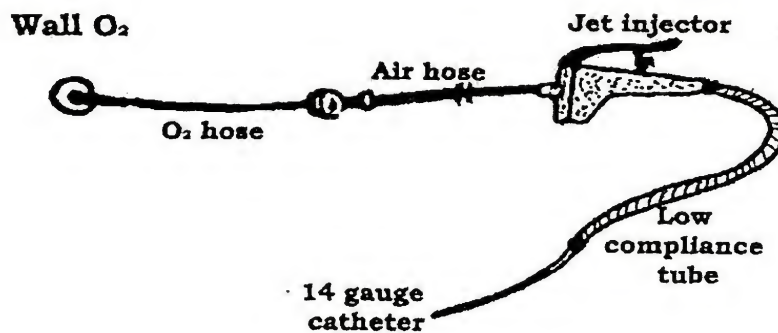


Figure 15-1; Manual jet ventilation

- Complications:

1. Air trapping and barotrauma resulting in pneumothorax, pneumo-mediastinum or s.c. emphysema.
2. Gastric dilatation with possible regurgitation.
3. Drying of mucosal surface.
4. Aspiration of resected material.
5. Complete respiratory obstruction.

- Contraindications:

1. Airway obstruction without tracheostomy.
2. Obesity.
3. Increased risk of aspiration.
4. Advanced COPD patients.
5. It is not suitable for removal of a foreign body.

7) High-Frequency Jet Technique:

- It is a variation of manual jet ventilation.
- It utilizes a small cannula or tube placed in the trachea through which gas is injected at 80-300 times per minute.

E.g. **Carden tube** which is made of malleable copper with a Luer connector at the proximal end that attaches to jet ventilation with rounded distal end.

Both (6) and (7) need TIVA for induction and maintenance.

3. Cardiovascular Stability:

- ABP and HR fluctuate markedly during laryngoscopy and may need invasive ABP monitoring because: The procedure resembles a series of stress-filled laryngoscopies and intubations separated by varying periods of minimal surgical stimulation.

4. Laser Precaution:

See below.....

Postoperative Management:

There is a risk of postoperative laryngospasm or edema extubation should be in the lateral position then give O₂ to decrease hypoxia.

Laser Surgery

- The word "Laser" is an acronym for

Light Amplification by Stimulated Emission of Radiation

Laser light differs from ordinary light in

It is - **Mono-chromatic** i.e. it (all photons) possesses one wave length.

- **Coherent** i.e. it (all photons) oscillates in the same phase.

- **Collimated** i.e. it (all photons) exists as a narrow parallel beam.

Types: According to its wavelength which is determined by the medium in which the laser beam is generated.

1- **CO₂ Laser:** It has **long wave length** (10600 nm) with low tissue penetration.

2- **Nd: YAG Laser** (Neodymium-Yttrium-Aluminum- Garnet gem): It has short wave length (1060 nm) with high tissue penetration.

3- **KTP Laser** (Potassium titanyl phosphate): It has short wave length (double the YAG frequency) with high tissue penetration.

4- **Argon Laser:** It has short wave length with high tissue penetration.

5- **Helium Neon Laser:** It has **very long wave length** with very low tissue penetration. Its red color is used for aiming the CO₂ and the Nd:YAG lasers.

Generally, the longer the wavelength, the less the tissue penetration.

Hazards of Laser:**A. For Patients:**

1. **Airway fire** (the most dangerous).
2. **Injury** to normal tissues adjacent to the operative field: e.g. tracheo-bronchial perforation of major pulmonary blood vessels, teeth...
3. **Hypoxemia** from inadequate ventilation and from distal collection of secretions, blood, debris and smoke is a major cause of morbidity and mortality.
4. **Eye damage.**
5. **Skin burns.**

B. For OR Personnel:

1. **Toxic vapor and fumes (laser plume)** from tissue vaporization leading to;
 - Detrimental effects on pulmonary airway resistance, gas exchange and muco-ciliary function.
 - It may be **infectious** to OR personnel as viable bacteria have been shown to be present in the laser plume (still not certain for viral particles as HIV, papilloma-virus and hepatitis).
2. **Eye damage.**
3. **Skin burn.**

Precautions for Laser:**1. Precautions for Airway Fire:**

1) **Avoid the use of ETTs**, use techniques that do not involve ETT e.g. intermittent apnea or jet ventilation.

2) If ETT is used, **use one of the following types;**

a. **Laser Resistant Tubes:** (Each tube type is resistant to a specific type of laser)

ANESTHESIA FOR E.N.T. SURGERY

- E.g.

- An air tight stainless steel tube with double PVC cuff.
- A soft rubber shaft tube covered with a corrugated silver foil which is then covered by a Merocel sponge covering. The Merocel is moistened with saline which consumes laser energy if it is struck.
- An aluminum tube covered with silicone and has a unique self inflating foam cuff.
- A red rubber tube with copper foil tape and covered with polyester sleeve.
- A silicone wrapped with Teflon-coated aluminum tape.

- Advantages:

- They are kink resistant tubes (for metal tubes).
- They are combustion-resistant tubes, but can still be ignited if enough laser energy is applied.

- Disadvantages:

- They have a thick wall (they have a larger outer diameter for a given inner diameter than conventional ETTs) and are not available in pediatric sizes so, they can not be used in small airways e.g. pediatric patients, tracheal stenosis, or obstructing lesions.
- They have a decreased flexibility.
- They have more difficult cuff inflation and deflation properties.
- They can transmit heat (for metal tubes).
- They can reflect laser resulting in injury to the surrounding tissues.

b. Polyvinyl Chloride (PVC) or Red Rubber Tubes:

- They are wrapped by aluminum foil in an overlapping spiral manner for several centimeters above the cuff. Today, this is a dangerous practice and should be avoided.

- Unwrapped tubes have the following disadvantages:

They are highly combustible;

- PVC tubes are more risky because they produce hydrochloric acid and other toxic compounds.
- Rubber tubes are less risky because they produce non-toxic compounds so, they are preferred.

- Wrapped tubes with a metallic tape have the following disadvantages:

- No cuff protection.
- Add thickness to the tube so, use 1-2 mm smaller size.
- Not an FDA approved device.
- Protection varies with the type of the metal foil used.
- Adhesive backing may ignite.
- They may reflect laser into the surrounding tissues.
- Rough edges may damage mucosal surfaces.
- Airway obstruction may occur from aspiration of detached pieces of foil.

(3) On using ETTs, as no tube is completely laser-proof, the following precautions should be taken:

- 1- Decrease the inspired O₂ concentration as low as possible and avoid N₂O as both support combustion. So use air (Helium)/O₂ 25% mixture. Some patients can tolerate 21% O₂ guided by pulse oximeter.
- 2- The cuff should be filled with saline (rather than air) to dissipate the heat and it is better to use saline dyed with methylene blue to signal cuff rupture.
- 3- Laser intensity and duration should be limited as much as possible.
- 4- Isolation of the lesion with saline-soaked pledgets (gauze) should be done to limit the risk of ignition.
- 5- A source of water e.g. 60 mL syringe should be immediately available in cases of fire.

* **Surgical instruments** should be **matte finished or ebonized** rather than polished to prevent reflection and inadvertent misdirection of the laser beam.

* All windows should be covered with black window shades.

Antibiotics may be given to treat superimposed infection.

- If complete airway obstruction arises, the FB needs to be extracted rapidly or **pushed down** to usually the right main-stem bronchus. This sometimes can be lifesaving.

Head and Neck Cancer Surgery

It includes: Laryngectomy, glossectomy, pharyngectomy, parotidectomy, hemimandibulectomy and radical neck dissection.

Anesthetic Problems:

1- Type of patients: They are usually **heavy smokers or alcoholics** (as etiological factors). So, careful preoperative assessment for **cardiac** (e.g. coronary artery diseases) **respiratory** (e.g. COPD) or **hepatic** function should be done.

2- Airway obstruction and difficult intubation: should be assessment preoperatively
So; • These patients may need **preoperative tracheostomy under local anesthesia**.

- **Personnel and equipment for emergency tracheostomy should be always available.**

Method of induction:

- Severe obstruction** (stridor at rest) needs **preoperative tracheostomy under LA**.
- Moderate obstruction** (may progress to severe obstruction on loss of consciousness) needs **awake fiberoptic** intubation in cooperative patients.
- Mild obstruction** in uncooperative patients needs **inhalational induction** and intubation at deep anesthetic levels.
- If there is **no risk of obstruction**;

Induction with a sleeping dose of an i.v. agent as thiopentone can be done.

- If easy mask ventilation, give suxamethonium to facilitate intubation.
- If difficult mask ventilation, deepen anesthesia by halothane for intubation.

N.B.; - I.v. agents are contraindicated if there are any doubts regarding the patient's ability to maintain a patent airway after loss of consciousness.

- All equipment for difficult intubation should be available.

3- Increased blood loss:

So; • Two large bore i.v. lines should be secured.

- Cross matched blood should be available.
- Monitors for blood volume as CVP and PCWP should be available.
- Controlled hypotension may be needed.

4- Venous air embolism:

So; • Monitors for **venous air embolism** e.g. precordial, esophageal stethoscope, trans-esophageal echocardiography.

5- Increased Temperature Loss: due to lengthy surgeries, large incision, increased blood loss so, warm fluids, warm blankets.....etc.

6- During Tracheal Transection: (tracheostomy is usually a part of head and neck surgery).

- 1st ventilate the patient's lung with 100% O₂ for 2 min.
- **Compatible connections for a non kinkable (reinforced) sterile tube** should be available before the trachea is divided.
- The patient is then disconnected, cuff deflated and the ETT is withdrawn to the larynx then the trachea is divided.
- Place a **new E.T.T.** into the trachea rapidly;
ensure its position by capnography and hearing the breath sounds then the tube is secured firmly. A laryngectomy tube can be used (figure 15-2).
- An increase in the peak inspiratory pressure immediately after the tracheostomy usually indicates a mal-positioned tube, bronchospasm



Figure 15-2; Laryngectomy tube

or debris in the trachea.

7- Injury to surrounding structure as;

- **Facial nerve:** The surgeon may request the omission of muscle relaxant to identify certain nerves e.g. facial nerves by direct stimulation to preserve them.
- **Injury of the pleura** leading to pneumothorax.

Nasal Surgery

Anesthetic Problems:

1- Increased blood loss so, nasal preparation by lidocaine and epinephrine, head up, and controlled hypotensionetc are needed.

2- Intubation: By **non-kinkable cuffed ETTs** e.g.:- Oral RAE tube.

Pack the posterior pharynx by a ribbon gauze to decrease the risk of blood aspiration. The presence of the pack should be marked in writing on the strapping which secures the tube to remind the anesthetist to remove it at the end of surgery.

3- Associated allergic reactions.

- Presence of nasal polyps is often associated with allergic reactions.
 - Bronchial asthma.
 - Allergy to NSAIDs e.g. aspirin, ketorolac so, avoid them.

4- Difficult face mask ventilation: is expected due to preoperative nasal obstruction e.g. polyps, deviated septum so, oral airway during mask ventilation is very helpful.

5- Eye protection:

- **Tape** the patient's eye closed to **avoid corneal abrasion** due to the proximity of the surgical field. One exception to this is during **endoscopic sinus surgery**, when the surgeon may wish to periodically check for eye movement during dissection due to the close proximity of the sinuses to the orbit.

6- Extubation:

- **Smooth** to avoid coughing and straining but this may increase **the risk of aspiration** so **awake extubation** in the lateral position **is the usual**.

Ear Surgery

Anesthetic Problems:

1- Measures to decrease bleeding during microsurgery: (one drop of blood can obscure the field).

By: • **Smooth induction** to avoid coughing and straining and avoid hypertensive response to intubation....

- 10-15 degree **head up** tilt to help venous drainage.

- **Controlled hypotensive anesthesia.**

- Local infiltration of 100 µg epinephrine - Its concentration must not be > 1: 100000

2- Intubation: By **non-kinkable oral ETTs**.

3- The effect of N₂O on the middle ear:

- Normally, there is no effect of N₂O on the middle ear due to patent Eustachian tube.
- On chronic inflammation e.g. otitis media or sinusitis, the Eustachian tube will be obstructed so, the middle ear cavity becomes closed. Therefore, N₂O will diffuse rapidly into the middle ear faster than nitrogen (N₂) (the major component of air) as N₂O is 34 times more soluble in blood than N₂, resulting in an increased pressure which is maximum about 4 min after induction. This causes hearing loss and tympanic membrane rupture.
- During tympano-plasty, the middle ear is open to the atmosphere and there is no pressure build-up. Once the surgeon has placed a tympanic membrane graft, the middle ear becomes a closed space so, N₂O can diffuse into this space leading to an increase in the middle ear pressure so, the

ANESTHESIA FOR E.N.T. SURGERY

graft may be displaced. Also, discontinuing N₂O after graft placement will create a -ve middle ear pressure so, the graft may be displaced also.

So, N₂O is either - Entirely avoided during tympano-plasty.

Or - Discontinued prior to graft placement by 10-15 min.

4- Identification of facial nerve during surgery:

- By a peripheral nerve stimulator.

- Theoretically, this needs a non-paralyzed patient, but actually, most anesthetists use muscle relaxants.

5- Postoperative nausea and vomiting: Ear surgery, especially if labyrinthine function is disturbed, produces postoperative vertigo and vomiting so, anti-emetics are essential.

CHAPTER 16

ANESTHESIA FOR

OPHTHALMIC SURGERY

Intra-Ocular Pressure (IOP)

Normal IOP = 12-20 mm Hg (mean = 15 mm Hg).

It is decreased in the upright position and increased in the supine position.

Factors Affecting IOP:

1. External Pressure on the Eye: It increases IOP e.g.;

- Injection of large local anesthetic volume into the orbit.
- The anesthetic mask.
- The surgical retractor.
- Retrobulbar hemorrhage.
- Improper prone position.

2. Vascular (Choroidal) Volume:

a. CVP:

- An elevated CVP increases ocular vascular pressure and decreases aqueous drainage resulting in an increased IOP e.g.
 - Valsalva maneuver-like as airway obstruction, coughing, vomiting and bucking on the ETT. This increases the IOP 30-40 mm Hg.
 - IPPV increases the mean intra-thoracic pressure (it can be compensated by the control of PaCO₂).
 - Trendelenberg position.

b. ABP: There is autoregulation.

- An increased ABP above the autoregulation ranges increases the IOP e.g.:
 - Valsalva maneuver.
 - Laryngoscopy and intubation.
 - Trendelenberg position.
- A decreased ABP below the autoregulation range decreases the IOP.
- As • ABP < 85 -90 mm Hg causes a marked decrease in the IOP.
 - ABP At 50-60 mm Hg, the IOP is zero i.e. atmospheric.

c. PaCO₂:

- An increased PaCO₂ leads to VD of the choroidal vessels causing an increase in the IOP e.g. hypoventilation.
- A decreased PaCO₂ leads to VC of the choroidal vessels causing a decrease in the IOP. e.g. hyperventilation.

d. PaO₂:

- An increased PaO₂ has no effects.
- A decreased PaO₂ results in VD of the ocular vessels causing an increase in the IOP.

3- Aqueous and Vitreous Volumes: (less important during surgery).

- Their reduction is important in treatment of glaucoma (pathological increase in IOP due to decreased aqueous drainage) results in decreased IOP.

By: • Osmotic dehydrating agents as - Mannitol 1-1.5 gm/Kg. - Sucrose 50% 1 gm/Kg.
 • Acetazolamide (carbonic anhydrase inhibitor) inhibits the Na⁺ pump which results in decreased aqueous production and increased drainage.

Applied Anatomy of the Orbit**The Cone:**

- It is the area between the 4 recti muscles and the posterior surface of the globe.
- A thin membrane envelops the eyeball from the optic nerve to the sclerocorneal junction, separating it from the orbital fat and forming a socket in which it moves.
- The sheaths of the recti muscles inter-connect in the perimysium in a complex and variable manner and form the walls of the cone.
- Movement of the Globe: is controlled by six extraocular muscles (EOMs).
- The common tendinous ring forms the fibrous origin of the 4 recti muscles at the apex of the cone.

The Oculo-Cardiac Reflex:

- **Stimulus:** Traction on EOMs (especially medial rectus) or pressure on the eye ball especially in • Pediatric patients.

- Surgery on EOMs (e.g. strabismus surgery).

- **Afferent:** Trigeminal nerve.

- **Efferent:** Vagal nerve.

- **Response:** Heart arrhythmias ranging from bradycardia and ventricular ectopy to sinus arrest or VF.

- **Prophylaxis:**

1. Anticholinergics: atropine or glycopyrrolate i.v. immediately before surgery, but they are dangerous in elderly patients who have some degree of coronary artery disease.
2. Retro-bulbar block (but the reflex still may occur with it).
3. Deep inhalational anesthetics (but the reflex may still occur with them).

Management:

- 1- Immediate notification of the surgeon and cessation of stimulation.
 - 2- Confirmation of adequate ventilation, oxygenation and depth of anesthesia.
 - 3- I.v. atropine 0.01 mg/kg if conduction disturbances persist.
 - 4- In recalcitrant episodes, infiltration of the rectus muscle with local anesthetics is done.
- N.B.; The reflex fatigues (self-extinguishes) with repeated traction on the EOMs.

Intra-Ocular Surgery

The choice between GA and LA should be made jointly by (The patient, the anesthesiologist, and the surgeon).

General Anesthesia for Ophthalmic Surgery**Aim:**

- 1- A moderate decrease in the IOP to prevent expulsion of the eye content via the surgical incision because if the IOP is increased, a sudden reduction in pressure on incision may cause expression of contents or expulsive hemorrhage.
- 2- Complete immobility of the eye especially for microsurgical procedure.

Indications of GA:

1. Eyes liable for complications e.g. diabetic patients.
2. Contraindications to local blockage as;
 - a. High myopia because it increases the risk of perforation.
 - b. Open eye injury because the pressure by the LAs behind the eye can cause extrusion of the intraocular contents via the wound.
 - c. An aphakic patient with a single functioning eye.

Anesthetic Problems:

1. Type of patients.
2. Avoid factors which increase the IOP e.g. straining, coughing....
3. The patient is away from the anesthetist.
4. Postoperative vomiting.
5. Postoperative analgesia.

Preoperative Management:

- Type of patients:
 - Patients are at the extremes of age. They are either;
 - **Pediatrics:** who may be suffering from congenital disorders e.g. Down syndrome.
 - **Geriatrics:** who may be suffering from systemic disorders e.g. hypertension, ischemia.
 - Patients may be apprehensive especially if there is a possibility of permanent blindness

Premedications:

- Sedatives: e.g. oral diazepam 0.1 – 0.2 mg/kg. Decrease the dose in elderly patients.
- Anticholinergics: especially in pediatrics to decrease the oculo-cardiac reflex.
- Antiemetics: e.g. metoclopramide 10 mg i.v. or ondansetron to avoid postoperative vomiting.

Intraoperative Management:

Induction: Smooth induction to avoid increased IOP.

- Avoid pressor response to intubation..... "see airway management".
- Avoid coughing and straining on intubation.
- Induction agents:
 - Propofol is of choice as it causes less postoperative nausea and vomiting.
 - Thiopentone is a good alternative.
 - Etomidate is of choice in elderly and unfit patients as they decrease the IOP and CVS stability, but care should be taken for;
 - Occurrence of unpredictable generalized myoclonus which increases the IOP so, it is avoided in open eye injury except if rapid and complete prior muscle relaxation is guaranteed.
 - As it is painful on injection; it causes stress so, it should be given in a large vein with 1-2 mL lidocaine 2%.
 - **Ketamine is avoided as it increases the IOP.**

• **Suxamethonium:**

It provides **an ideal condition** for intubation with a minimal risk of coughing or straining because it produces intense muscle relaxation. It causes a transient increase in IOP which disappears by the time the surgery starts.

- Non-depolarizing muscle relaxants are a good alternative.
- Intubation:
 - ETT is routinely used.
 - Recently, some authors prefer **laryngeal mask** (an armored tube laryngeal mask is more preferred). It can be used with controlled ventilation.

Advantages: • Easily inserted.

- Avoid postoperative coughing, straining of laryngospasm (which occurs with ETT).

Disadvantages: • It is not suitable for patients who are at a risk of aspiration.

E.g. open eye injury, morbidly obese patients, ... etc.

ANESTHESIA FOR OPHTHALMIC SURGERY**Monitoring:** Standard +

- Body temperature: In contrast to most pediatric surgeries, infant body temperature often increases during ophthalmic surgeries due to; - Head to toe draping.
 - Insignificant body surface exposure.
- Peripheral nerve stimulator to guarantee that no cough, straining or patient movement occur.

Maintenance:

Controlled ventilation is used to produce moderate hyperventilation.

- Non-depolarizing muscle relaxants are given before the action of suxamethonium ends to ensure that no coughing or straining occur with the help of a peripheral nerve stimulator.
- 15° head up tilt.

Extubation:**Smooth extubation**

- By (1) Deep extubation.
 - (2) I.v. lidocaine 1.5 mg/Kg 1-2 min before extubation.
- This technique is not suitable for patients at increased risk of aspiration.

Postoperative Management:

- 1- Postoperative Vomiting.
- 2- Postoperative Analgesia.

Traumatic (Penetrating, Open) Eye Injury

- The IOP is equal to the atmospheric pressure (i.e. zero) due to the opening of the eye to the outside but, increased choroid and vitreous humor volume may cause extrusion of the eye content via the wound.
- Most patients are with **full stomach**. The patients must be considered to have a full stomach if the injury occurred within 8 hours of the last meal even if the patient has not eaten for several hours since the injury, because gastric emptying is delayed by the pain and anxiety following the trauma.

Anesthetic Management:

- **Only general anesthesia** is used.
- The same anesthetic management "as before" except:

Premedication:

- Avoid aspiration by:
 1. Metoclopramide i.v. 10 mg repeated every 2-4 hours till surgery.
 2. H₂ blockers as cimetidine 300 mg i.v., Ranitidine 50 mg i.v. or Famotidine 20 mg i.v.
 3. Antacids just before induction as their duration of action are 30-60 min only, but they increase gastric volume.
- Avoid gastric evacuation by nasogastric tubes as this precipitates coughing, and straining which increase IOP.

Induction:**Modified rapid sequence induction.**

- Gently applied face mask with 100% O₂ for several minutes is needed.
- Blunt the stress response of intubation by β blockers, Ca⁺⁺ channel blockers, lidocaine or midazolam.
- + Cricoid pressure (poorly applied cricoid pressure may block venous drainage of eye)
- By • **Non-depolarizing muscle relaxants** (using relatively larger doses):
 - e.g. Rocuronium → onset 60-70 sec, of choice

The onset of non-depolarizing muscle relaxants can be increased by giving a priming dose (Give a small dose 1st then give the full dose "see details before".....).

• **Suxamethonium:**

Some prefer avoiding it as it produces a transient increase in IOP in open eyes, but the effect of laryngoscopy and intubation on IOP is much more than the effects of suxamethonium.

So, measures to decrease the pressor response of intubation can abolish the effect of suxamethonium so, it can be used especially if difficult intubation is suspected.

- **Avoid pressure on the injured eye with the mask** during preoxygenation, the eye can be patched with Fox shield.
- Avoid spraying the larynx with local anesthetics as this may blunt the protective reflexes.
- The use of the laryngeal mask is avoided.

Extubation:

Awake extubation in the lateral position.

Regional Anesthesia for Ophthalmic Surgery

Patient Selection:

Indications: It is suitable for;

- Elderly patient.
- Medically compromised patient.

Contraindications: It is unsuitable for;

- Young patients.
- Extreme myopia (as there is increased risk of perforation).
- Open eye injury (as the pressure from injecting fluid behind the eye may cause extrusion of intra-ocular content through the wound).
- Patients with mental disability.
- Patients with physical disability (can not lie still).
- Coagulopathies or warfarin therapy (LA can be safely done if preoperative INR value is in the therapeutic range).
- Aphakic patients.

Patient Preparation:

1- **Preoperative visit** is important for establishment of friendly rapport with the patient.

2- **Preoperative examination (and recording)** for;

• **The axial length** of the eyeball by **ultrasound scan**. Normally it is 20-24 mm. In highly myopic patients, there is an increase in axial length > 25 mm increasing the risk of global perforation and so, they should be treated with caution.

• **Extra-ocular muscle and facial nerve** because local anesthesia is avoided in patients with myopathies or Bell's palsy.

3- **An informed consent** is obtained from the patient.

3- **I.v. access** should be secured.

4- **Full cardio-pulmonary resuscitation** equipment should be available.

5- **I.v. sedation:**

- E.g. Midazolam 1-3 mg ± Fentanyl 12.5 – 25 µg is a common regimen.

Monitoring: Standard

Technique:

After sterilization of the eye;

1- There must be an anesthetist: to;

- Monitor the patient (i.e. **Monitor Anesthesia Care, MAC**).
- Treat complications.
- Induce general anesthesia at any time if needed.

2- Primary Gaze Position:

- During performing the block the patient should look straight ahead in the **primary gaze position** (the safest position) as;
 - On looking upward or up and inward, the optic nerve is put in the path of the needle.
 - On looking downward or down and outward, the optic nerve is stretched so, it is easily punctured (figure 16-1).

3- Depth of Injection:

- Injection should not be deeper than **31 mm** from the orbital margin as this ensures that

the needle will not approach the apex of the orbit

as the chance of penetrating the optic nerve or damaging other important structure increases with the increased depth of the injection.

- The mean distance from the temporal border of the orbital margin to the optic foramen is 50 mm.

4- The Needle Used:

- The best size is **25 gauge needles**.
- The best length is **2.5 cm long needles**.
- **Sharp needles** are used as blunt needles cause more trauma and pain which may produce vaso-vagal syncope.
- The operator should consistently use **the same volume syringe with the same gauge** needle so, he can feel the resistance to the injection and can detect easily any change in the resistance, as correctly placed injections have minimal resistance.
- The operator should make sure that the hand used to hold the syringe and needle in a **pen fashion stays in firm contact with the patient's cheek** so that any unexpected movement by the patient does not displace the needle.

5- Local Anesthetics Used:

- Combinations are used. Equal volumes of **bupivacaine 0.5-0.75% + lignocaine 2-4 %**.
- Bupivacaine increases the duration of the block and allows postoperative analgesia.
- Lignocaine speeds the onset of the block and it is less toxic.

6- Additives to Local Anesthetics:**a. Hyaluronidase:**

Value: It hydrolyses connective tissues polysaccharides causing;

- Improvement of LA spread and efficacy.
- LAs can be placed more anteriorly in the orbit (making the technique more safe).

Dose: 5 Units for each 1 mL of LAs.

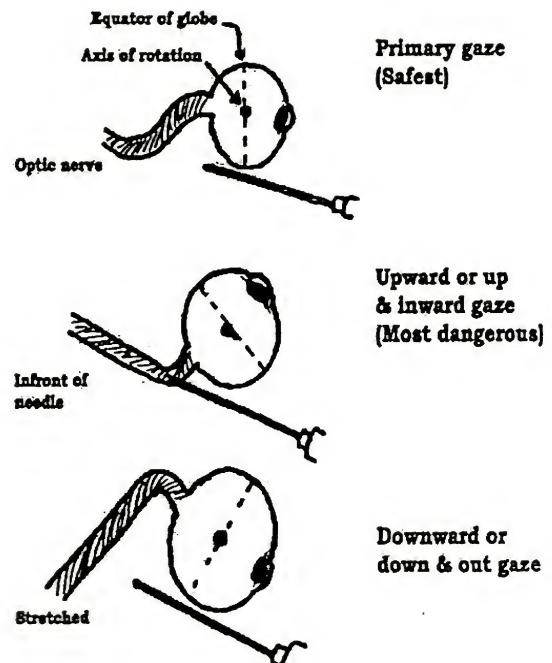


Figure 16-1; The position of the eye.

b. Epinephrine:

Value: It causes VC of blood vessels resulting in;

- Improvement of LA duration and solidity.
- Decreasing the incidence of hemorrhage.

It can be omitted for medical causes.

Dose: 1: 400 000 solution.

7- Extra-ocular Pressure Application:

- This is important to disperse the local anesthetic injected resulting in;
 - Increasing its spread.
 - Decreasing the extra-ocular volume. This decreases the pressure on the eye decreasing IOP.
- It is done by either;
 - Gentle digital pressure and massage for at least 20 min.

Or • A **pressure-reducing device such as Honan's balloon**, it is applied for at least 20 min and at a pressure of no greater than 35 mm Hg (at this pressure, blood supply to the eyeball is assured). Then the balloon should be removed just before the operation.

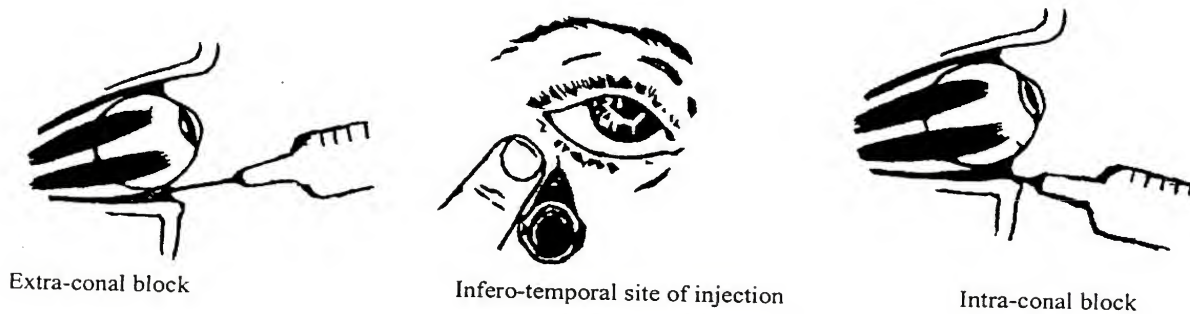
8. Techniques of Performing the Block: It is either (figure 16-2);

Figure 16-2; Eye block

A- Extra-conal (peri-conal or peri-bulbar) block	B- Intra-conal (Retro-bulbar) block
<ul style="list-style-type: none"> - It is analogous to epidural block with delayed onset (the time for LAs to diffuse via the connective tissue of the cone). - It places the LAs outside the cone depending on variable diffusion across the facial layers. - It needs; <ul style="list-style-type: none"> • Larger volumes: 5 mL for each injection. • Higher concentrations. - Technique: <ul style="list-style-type: none"> • While the patient is looking straight ahead, the anesthetist use his index finger to palpate the groove between the eyeball and the orbital margin and insert the needle at the junction of the middle and the lateral 1/3 (infero-temporal quadrant) perpendicular on the skin as the tip of the needle passes the equator of the eyeball, it is redirected slightly supero-medially then aspiration and injection are done. • Additional injection just medial to the medial canthus may be done. • Additional injections may be needed. 	<ul style="list-style-type: none"> - It is analogous to subarachnoid block with rapid onset - It places the LAs inside the cone in the fatty compartment which surrounds the optic nerve. - It needs; <ul style="list-style-type: none"> • Smaller volumes: 3-4 mL. • Lower concentrations. - Technique: <ul style="list-style-type: none"> • The same as infero-temporal injection of extra-conal but as the tip of the needle passes the equator of the eye, it is redirected more superiorly and medially to float into the cone with minimal resistance. - In both; <ul style="list-style-type: none"> • Slight movement of the needle to insure that it is not attached to the globe. • After injection, the needle is withdrawn in the reverse direction of insertion. • Avoid injections at the supero-nasal quadrant as

<p>- Facial nerve block: No need to be blocked as its fibers are blocked during spread of the anesthetics superficially while they enter the orbicularis oculi muscle.</p>	<p>they may damage the trochlear apparatus or cause hemorrhage. - Facial nerve block: It should be blocked separately see below.....</p>
--	--

Facial Nerve Block (For intra-conal block only)

Value: It weakens the orbicularis oculi muscle, so avoiding the squeezing action of the eyelids.

Methods: (Figure 16-3)

1- **O'Brien:** The simplest.

- Using the most prominent part of the zygoma, midway between the tragus of the ear and the lateral orbital margin as the landmark.
- A 25 gauge 30 mm needle is inserted perpendicularly down to the zygoma, withdrawn from the periosteum and aspiration are done then 3-6 mL are injected lateral to the lateral orbital margin.
- Gentle massage should be applied to the weal to spread LAs and to ensure that no bleeding occurs.

2- **Atkinson.**3- **Van lint.**

4- **Nadbath:** It blocks the facial nerve as it exits the stylomastoid foramen under the external auditory canal.

N.B.; 1-3 mL of LAs injected just under the orbicularis oculi muscle may be done by some authors to block the terminal fibers of the facial nerve to enhance facial nerve block.

9- **Successful Block:**

Is indicated by; • Anesthesia of the eye.

• Akinesia of the eye.

• Abolishment of the oculo-cephalic reflex (i.e. blocked eye does not move during head-turning).

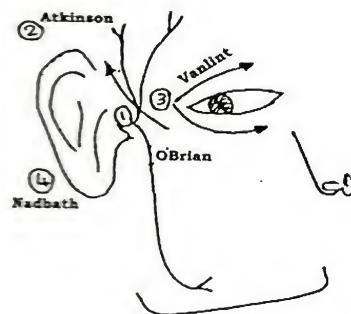


Figure 16-3; Facial nerve block

Complications:**1. Hemorrhage:**

- C/P: It is either concealed or revealed.

a. **Venous hemorrhage:**

It appears as marked blood stained echymosis.

Extravasation of blood into the peri-orbital tissues occurs causing a mild increase in IOP.

b. **Arterial hemorrhage:** It is more serious.

Extravasation of blood into the peri-orbital tissues occurs causing a marked increase in IOP.

- **Prevention:**

1- Preoperative control of hypertension.

2- **Avoid;**

• **Multiple injections** as the fewer the injections into the orbit, the less the damage to the blood vessels.

• **Cutting and slicing movements** at the needle tip.

• **Thicker needles.**

• **Deep intra-orbital injections.**

3- **Recommendations;**

• The **infero-temporal quadrant** as it has fewer blood vessels and is less hazardous.

• A technique of producing a **liquid stilette of LAs** in front of the advancing needle by slow injection.

- **Adrenaline** as it decreases the incidence of hemorrhage.
- **Firm digital pressure** applied to the orbit as soon as the needle is withdrawn after intra-orbital injections.
- **Blunt** Atkinson-type needles can be used, but are painful to be inserted. They may cause **vaso-vagal syncope** and can still damage blood vessels.
- **Treatment:** (to decrease IOP)
 - a. **Venous Hemorrhage:**
 - Digital massage.
 - Cautious applications of IOP-reducing devices.

Before the decision is made to proceed with surgery or postpone it for a few days, it is advisable to measure and record the IOP.

b. **Arterial Hemorrhage:**

- Firm digital pressure usually stops the bleeding.
- Lateral canthotomy.
- I.v. acetazolamide.
- I.v. mannitol.
- Paracentesis.

2. Central Spread:

- **Mechanism:**

- a. LAs reach the CNS (and/or cross the optic chiasma to the opposite eye) **around the optic nerve as cerebral dura matter provides a tubular sheath for the optic nerve** which fuses with its epineurium and is continuous with the sclera so, the needle's tip may perforate this optic nerve sheath. Onset of symptoms: They usually occur within **15-20 min after the injection** so, it is advisable not to cover the patient's face on the operating table during this period.
- b. Rarely, LAs reach the CNS in a **retrograde fashion up the orbital artery**, when it is cannulated by the needle's tip. Onset of symptoms: They usually occur **instantaneously** and orbital hemorrhage usually occurs.

- **C/P:**

- It is variable depending upon which part of CNS is affected by the LAs.
- **The midbrain** is the usual affected area due to its anatomical proximity to the optic nerve resulting in;

1. **C.V.S: instability up to cardiac arrest.**
2. **Respiratory depression:** up to respiratory arrest (**post-retrobulbar apnea syndrome** occurs within 15-20 min and resolves within 1- 1.5 hours).
3. **Temperature** regulation disturbances.
4. **Vomiting.**
5. **Temporary hemiplegia.**
6. **Aphasia.**
7. **Generalized convulsions.**
8. **EOMs palsy in the opposite eye** due to affection of the contra-lateral oculo-motor and trochlear nerves with loss of vision (amaurosis) is pathognomonic of CNS spread.

- **Prevention:**

1. Patients should look straight ahead in the **primary gaze** position as the optic nerve is slack and out of the way of the advancing needle. If the needle touches the optic nerve it will push the optic nerve aside due to its slackness.
2. **Avoid deep** intra-orbital injections as the optic nerve is tethered to its sheath as it merges through the optic foramen.

ANESTHESIA FOR OPHTHALMIC SURGERY

3. **Withdrawal of the needle 1 mm from its maximum depth before injection** is recommended.
- **Treatment:** symptomatic throughout the duration of LA action usually 1-1.5 hours by;
 1. Intensive monitoring.
 2. Cardio-pulmonary resuscitation by adrenaline, and IPPV.
 3. Thiopentone to control convulsions.
 4. When the patient is stable, continue surgery with general anesthesia.

3. Puncture of the Eyeball:

- It is very rare as **the sclera is a tough structure** and in most cases is **not perforated easily**.
- Puncture of the eyes occurs especially in;
 - * High myopia with axial length > 25-35 mm.
 - * Previous retinal hemorrhage.
 - * Posterior staphyloma.
 - * Deep sunken eyes with a narrow orbit.

- Treatment:

Global puncture is often a **double puncture of the posterior segment** of the eyeball where the tip of the needle is in the cone at the time of injection. It leads to a **good block**, but the puncture is usually recognized at the time of surgery by the **softness of the eye**. Damage in the posterior segment may not be observed and a **band of scar tissue** will occur at the site of the needle track. If it is **not excised**, it may **contract and detach the retina resulting in sudden blindness**.

4. Optic Nerve Damage:

- It is rare, **due to obstruction of the central retinal artery** as injury of the artery causes a **hematoma** within the optic nerve sheath. This causes **compression and obstruction of blood flow**.

5. Myopathy of EOMs:

- Due to inadvertent injection of LAs into EOMs. It causes prolonged weakness of the muscles.

6. Vasovagal Syncope:

- Especially: - In young and anxious patients.
 - With blunt Atkinson needle, due to painful insertion.
- Treatment: - O₂.
 - Anticholinergics.
 - Head down position.
 - It should be differentiated from central spread by testing the vision and EOMs in the opposite eye.

Squint (Strabismus) Surgery**Anesthetic Problems:**

- 1- There is an increased incidence of;
 - **Oculo-cardiac reflex.**
 - **Malignant hyperthermia.**
- 2- **Avoid drugs with prolonged action on the muscle tone** as postoperative adjustable sutures may be planned.
Ketamine is preferred in children as **it does not decrease the muscle tone** so, it allows the surgeon to test muscle power intraoperatively.
- 3- **There is an increased incidence of postoperative nausea and vomiting** so, prophylactic antiemetics are essential.
- General anesthesia is usually done of any anesthetic technique.

CHAPTER 17

ANESTHESIA FOR GIT DISEASES

Intestinal Obstruction

Preoperative Management:

1) Fluid and Electrolyte Imbalance:

a. Dehydration:

- Normally, 7-9 liters of fluids are secreted into the upper intestinal tract daily.
- In small intestinal obstruction, fluid loss occurs due to
 - Accumulation of fluids in the bowel above the obstruction.
 - Increased secretion due to PG release in response to an increased intra-luminal pressure.
 - Decreased reabsorption once the intra-luminal pressure exceeds 20 cm H₂O.

This causes loss of isotonic salt (plasma like) water resulting in isotonic contraction of ECF volume. So; dehydration and an increased hematocrit occur.

- At early stages —————→ 1500 mL of fluid accumulate in the bowel.
- At well established cases with vomiting —————→ 3000 mL of fluid accumulate in the bowel.
- At late stages with hypotension and tachycardia → 6000 mL of fluid accumulate in the bowel.
- The degree of dehydration is evaluated by the duration of illness, presence of vomiting, skin elasticity, sunken eye, oliguria, ABP, UOP, HR, and CVP.

.....See details → Anesthesia with CVS disease – (Shock).

The degree of ECF loss can be monitored by serial hematocrit (Hct) determinations. A rise in the Hct is proportional to the amount of fluid loss e.g. If Hct increases to 55%, this indicates that about 40% of plasma and ECF volume have been lost.

- Treatment:

2-6 liters of i.v. fluids are needed according to the degree of dehydration by lactated ringer (it is of choice because the fluid lost is similar to the plasma) or normal saline.

b. Electrolyte Disturbances:

1. Hyponatremia and Hypochloremia:

- Because the accumulated fluid in the bowel and vomitus contains high concentrations of Na⁺ and Cl⁻ ions.

2. Hypokalemia: mainly due to renal mechanisms.

2ry to metabolic alkalosis i.e. after low Cl⁻ ion concentration, there is exchange of Na⁺ for K⁺.

2ry to hyperaldosteronism due to the loss of water.

Hypokalemia should be corrected by i.v. K⁺ infusion.

c. Acid-Base Imbalance:

Metabolic Acidosis: more common.

- Due to
 - Dehydration and loss of alkaline intestinal secretions.
 - Starvation ketosis.

Generally,

- High small intestinal obstruction causes severe dehydration, electrolyte and acid base disturbances.
- Low small intestinal obstruction causes mild dehydration, electrolyte and acid base disturbances because fluid is reabsorbed above the obstruction.

ANESTHESIA FOR GIT DISEASES

- **Large** intestinal obstruction causes **minimal** dehydration, electrolyte and acid base disturbances because fluid sequestration progresses more slowly as the large bowel is a primary storage organ with little secretory and absorptive functions.

2) Bowel and Abdominal Distention:

- Bowel distention occurs due to accumulation of fluids and gases resulting in;
 - **Blockade of the venous outflow:** This causes subsequent extravasation of blood and fluids into the bowel wall leading to **edema of the bowel wall**.
 - **Blockade of the blood supply** to the obstructed segment: This causes **strangulation** which increases the permeability of the bowel wall with loss of RBCs into the bowel and peritoneal cavity (this may need to be restored by whole blood or packed RBCs). Also, there is a leak of toxic materials into the peritoneal cavity which may cause **septic shock**.
 - **Hindering of diaphragmatic movement:** This causes inadequate ventilation.
 - **Decreasing venous return** due to;
 - Distention which decreases the negative intra-thoracic pressure leading to a decrease in VR.
 - Direct veno-caval compression by intra-peritoneal tension which decreases VR.

On surgical incision, sudden escape of fluids into the peritoneal cavity may cause severe hypotension so, allow gradual escape of fluids and monitor BP frequently during incision.

- **Progressive distention** may cause **rupture of the colon** (usually at the cecum) especially in the presence of a competent ileocecal valve.
- **Progressive distention** may cause a **tense abdominal wall**. This causes;
 - Higher incidence of reverse peristalsis.
 - More need of deeper anesthesia and muscle relaxants to provide adequate operative conditions.

So, **abdominal decompression** is done preoperatively by **naso-gastric tube**.

3) Respiratory Problems:

- Due to
 - **Abdominal distention** which **hinders the diaphragm** resulting in inadequate ventilation. This decreases tidal volume and functional residual capacity and causes a decrease in PaO_2 and an increase in PaCO_2 .
 - **Weakness of intercostal muscles** due to **hypokalemia**.

4) C.V.S. Problems:**a. Hypotension and Tachycardia up to shock.**

- Due to
 - **Hypovolemia**.
 - **Decreased VR**.
 - **Septic shock** due to trans-peritoneal absorption of toxins from the gangrenous loop.
 - **Hyponatremia** also causes confusion and somnolence.

b. Arrhythmias (Ventricular):

- Due to **hypokalemia**.

5) Vomiting, Regurgitation and Aspiration:

- **Reversal of peristalsis and mechanical obstruction** pushes the intestinal juice in addition to the gastric juice to produce a full stomach with an increased intra-abdominal pressure. This increases the incidence of vomiting and regurgitation especially in higher levels of obstruction.

6) Poor General Condition of the Patient:

- Patients are often,
 - **Old** with preexisting **lung or heart disease**.
 - **Feverish**.
 - **With acute abdominal pain:** Pain is colicky and diffuse and alternates with quiescent periods. The duration of the quiescent period depends on the site of intestinal obstruction.

- With high obstruction, it is about 4-5 minutes.
- With low ileal obstruction, it is about 15-20 minutes.
- With strangulation, it is a **steady** severe pain.
- **Leukocytosis** (usually 15000 – 25000 /mm³) indicates strangulation.

Preoperative Investigations: Standard +

1- X-ray abdomen in supine and erect position:

To ensure diagnosis of intestinal obstruction as gas-fluid levels occur.

N.B.; Gas-fluid levels can occur also in gastroenteritis, severe constipation, and severe aerophagia.

2- Investigations to detect complications:

- Hct.
- WBCs.
- Electrolytes, acid base disturbances.
- Arterial blood gases PaO₂ and PaCO₂.

Premedications:

- Avoid all oral premedications.
- Avoid drugs that may **inhibit respiration** e.g. opioids, sedatives...
- Avoid anticholinergics e.g. atropine if fever or tachycardia occur.
- Avoid antacids or H₂ blockers although there is a risk of aspiration as;
 - They may stimulate vomiting.
 - They are of low value if a large **volume** of fluids are already sequestered in the bowel e.g. high intestinal obstruction.

Intraoperative Management:

Choice of Anesthesia:

- Regional Anesthesia** (subarachnoid or extradural)

It is avoided if significant fluid depletion is suspected.

- General Anesthesia:**

Monitoring:

Standard + UOP, CVP, and PCWP.

Induction and Intubation:

There is a major risk of aspiration causing very high mortality rates.

So either:

1. Awake Intubation:

- Especially in a cooperative patient.
- By spraying the patient's lip, tongue **and** pharynx with topical anesthetics.
- N.B.; Avoid anesthesia of the larynx by superior laryngeal nerve block or trans-tracheal injection in these patients to avoid **loss of protective** reflexes of the larynx against vomiting or regurgitation.
- Then do laryngoscopy and intubation **followed** by induction by i.v. agents.

2. Rapid Sequence crash Induction:

- It is done in supine or lateral position **with** head down tilt (10°) to avoid aspiration if vomiting occurs.
- N.B.; Some prefer head up position to decrease the **incidence** of regurgitation by the effect of gravity on the stomach content, but it increases the risk of aspiration if **vomiting** occurs.
- Preoxygenation: 8-10 L of 100% O₂ for 3-5 min via a well-fitting mask is essential.
- Precurarization (defasciculation) **dose of non-depolarizing** muscle relaxants to avoid suxamethonium fasciculations. **Recently**, it was proven that fasciculations, although they increase intra-gastric pressure, but they also increase the tone of the lower esophageal sphincter therefore, not increasing the risk of aspiration.
- The naso-gastric tube should be **removed** before intubation (and may be reintroduced after intubation) to:

ANESTHESIA FOR GIT DISEASES

- Allow effective cricoid pressure.
 - Avoid causing esophageal sphincter dysfunction.
 - Avoid hindering of laryngoscopy and intubation.
 - **Cricoid pressure (sellick's maneuver):** should be done by a trained assistant from the moment of loss of consciousness till the ETT is correctly placed (confirmed by auscultation and capnography) and its cuff is inflated.
- N.B.; If cricoid pressure is properly done, it provides a barrier against at least 100 cm H₂O of esophageal pressure.
- I.v. agents - Thiopentone is a good choice if there is no hypotension.
 - Ketamine or Etomidate are good choices if there is hypotension.

Maintenance:

- O₂ + Potent inhalational agent + Non-depolarizing muscle relaxant + IPPV
- Careful titration of doses of inhalational agents is needed to avoid severe hypotension.
 - **N₂O should be avoided** in bowel obstruction because it increases gas distention which **increases intra-luminal gas volume and pressure. This results in;**
 - More increased abdominal distention.
 - Increased bowel ischemia and necrosis.
 - Difficulties with abdominal closure at the end of surgery.

Extubation:

- **Awake extubation** in the left lateral position.
 - After returning of upper airway reflexes.
 - After good suctioning (the suction is kept ready).

Then keep the patient in this position afterwards.

Postoperative Management:

Continue the preoperative management (Fluid and electrolyte correction, Respiratory and CVS monitoring)

1- Postoperative Fluid Loss and Auto-infusion:

- In the **immediate postoperative period**, **significant fluid loss is seen mostly secondary to 3rd spacing**. This fluid loss gradually decreases over time. Usually by **about the 3rd postoperative day**, there is a reverses in direction as **fluid is transferred back into the vascular compartment i.e. auto-infusion** which may be added to the daily fluid requirements of the patient resulting in **congestive heart failure** especially if the patient is elderly with limited multi-organ reserves.

2. Postoperative Ileus:

- Due to **hyponatremia and hypokalemia**.

So, repeated (serial) determination of s. Na⁺, and K⁺ should be done and managed.

3. Postoperative Abdominal Decompression:

- It should be continued for **5-6 days** postoperatively because return of normal intestinal motility is usually prolonged after surgical relief of bowel obstruction (N.B.; after routine abdominal operations, the bowel function returns on about the 3rd postoperative day).

4- Postoperative Respiratory Problems (Hypoventilation): - Because;

1. Although the intestinal obstruction has been relieved, significant **abdominal distention** may remain **hindering the diaphragmatic motion**.
2. **Abdominal pain** is present.
3. **Residual effects of inhaled anesthetics, and i.v. anesthetics** are still present.
4. **Causes of difficulty of reversal muscle relaxants**.....
5. As after any upper abdominal surgery, there is a **15-20% reduction in functional residual capacity** which remains abnormal for more than a week.

CHAPTER 18

ANESTHESIA WITH LIVER DISEASES

Liver Function Tests

Many tests such as s. transaminases reflect hepatocellular integrity more than the hepatic function. Only s. **albumin** and **prothrombin time (PT)** reflect the hepatic function.

	AST (SGOT)	ALT (SGPT)	Alkaline phosphatase	γ - glutamyl trans- peptidase	5'- nucleo- tidase	Bilirubin	Albumin	PT
• Prehepatic (biliary production)	N	N	N	N	N	↑ Unconj. fraction	N	N
• Intrahepatic (Hepatocellular)	↑ to ↑↑↑	↑ to ↑↑↑	↑	0 to ↑↑↑	0 to ↑	0 to ↑↑↑ conj. fraction	0 to ↓↓↓	↑ to ↑↑↑
• Posthepatic (biliary obstruction) (cholestasis)	↑	↑	↑ to ↑↑↑	↑↑↑	↑ to ↑↑↑	0 to ↑↑↑ conj. fraction	0 to ↓↓↓	0 to ↑↑↑

1. Serum Bilirubin:

- Normally, the total bilirubin is $< 1.5 \text{ mg/dL}$ ($< 25 \text{ } \mu\text{mol/L}$) (Direct is $< 0.25 \text{ mg/dL}$ and indirect = the difference).
- Jaundice is obvious clinically when total s. bilirubin exceeds 3 mg/dL .

2. Serum Amino-transferase (Transaminases):

- S. aspartate amino-transferase (AST) = S. glutamic-oxaloacetic transaminase (SGOT). It is secreted from the liver, heart, skeletal muscle and kidneys.
- S. alanine amino-transferase (ALT) = S. glutamic-pyruvic transaminase (SGPT). It is specific for the liver.
- Normal serum levels for each are $< 35 - 45 \text{ Units/L}$.
- They are released in response to hepatocellular injury. Absolute levels generally correlate poorly with the degree of hepatic injury.
- Postoperative increased levels may be due to;
 - Skeletal muscle damage by preoperative i.m. injection or by surgery.
 - Hepatocellular injury (they are increased to 3 times the normal).

3. Serum Alkaline Phosphatase:

- Normally = $45 - 125 \text{ Units / L}$.
- It is present in the **liver, bone, small intestine, kidneys, placenta and bile duct cells** so; a slight degree of biliary obstruction increases its level up to 3 times the normal. So, it can differentiate between hepatic dysfunction due to biliary obstruction and due to hepatocellular damage.
- Simultaneous measurement of s. γ - glutamyl trans-peptidase (its normal level is $10-40 \text{ units / L}$) is important to exclude extra-hepatic sources of phosphatase elevations e.g. pregnancy, bone secondaries.
- N.B.; Although γ - glutamyl transpeptidase is released from organs other than the liver (kidneys, heart, lungs, pancreas, intestine and prostate) the combination of it with increased alkaline phosphatase strongly suggests hepato-biliary disease.
- 5'- nucleotidase is also measured (but it is increased in late pregnancy too).

ANESTHESIA WITH LIVER DISEASES**4. Serum Albumin:**

- Normally = 3.5 – 5.5 gm/dL.
- It is synthesized only in the liver. Its half life is 2-3 weeks so, it may initially be normal with acute liver disease.
- If s. albumin decreases, the free drug fraction increases resulting in an increase in the drug action.
- Values < 2.5 gm/dL indicate;
 - Chronic liver disease.
 - Malnutrition.
 - Increased loss in the urine e.g. nephrotic syndrome.
 - Increased loss in GIT e.g. protein-losing enteropathy.

5. Blood Ammonia:

- Normally = 80 – 110 mg/dL = 47-65 mmol/L.
- If it is markedly increased, it indicates hepatocellular dysfunction due to disruption of hepatic urea synthesis.

6. Prothrombin Time:

- Normally = 11 – 14 seconds.
- It measures the activity of fibrinogen, prothrombin factors V, VII and X.
- It can be corrected by vitamin K.

Postoperative liver dysfunction may occur.

- 1- **Mild postoperative liver dysfunction** occurs in a healthy person due to the reduction of HBF by anesthesia, surgical procedures, and sympathetic stimulation.
- 2- **Persistent postoperative liver dysfunction** occurs due to;
 - Viral hepatitis (usually transfusion- related).
 - Sepsis.
 - Idiosyncratic drug reaction.
 - Surgical complications.
- 3- **Postoperative jaundice** occurs due to;
 - a. Prehepatic (increased biliary production):
 - Large hematomas (the commonest).
 - Blood transfusion (acute hemolytic and delayed hemolytic reactions).
 - Hemolysis.
 - b. Hepatic (hepatocellular dysfunction):
 - Underlying liver disease or cirrhosis.
 - Ischemic or hypoxic injury.
 - Drug induced.
 - Gilbert's syndrome.
 - Intrahepatic cholestasis.
 - Sepsis.
 - c. Posthepatic (biliary obstruction, cholestatic):
 - Postoperative cholecystitis.
 - Postoperative pancreatitis.
 - Retained common bile duct stone.

Liver Diseases and Anesthesia

1. Hepatitis (acute and chronic).
2. Cirrhosis.
3. Hepato-biliary disease.
4. Hepatic surgery.
5. Hepatic transplantation.

Hepatitis

Acute Hepatitis:

Causes:

1- Viral Hepatitis:

- Hepatitis A and E are transmitted by feco-oral route.
- Hepatitis B is transmitted by percutaneous, venereal and contact with body fluids.
- Hepatitis C is transmitted by percutaneous, and contact with body fluids.
- Hepatitis D (Delta virus) is transmitted by feco-oral and percutaneous routes (with virus B).
- Others e.g. Epstein-Barr virus, Herpes simplex, Cytomegalovirus, and Coxsackie virus.

2- Exposure to Hepato-Toxins and Drugs:

- Toxic (with overdose):
 - Alcohol
 - Trichloroethylene
 - Carbon tetrachloride
 - Acetaminophen
 - Poisonous mushrooms.
 - Yellow phosphorus
 - Vinyl chloride
 - Salicylates
 - Tetracycline
- Idiosyncratic:
 - Volatile anesthetic (halothane)
 - Rifampicin
 - Phenytoin
 - Indomethacin
 - Sulfonamides
- Toxic and idiosyncratic:
 - Methyldopa
 - Isoniazid
 - Na Valproate
 - Amiodarone.
- Iry cholestatic:
 - Chlorpromazine
 - Cyclosporine
 - Methimazole
 - Chlorpropamide
 - Anabolic steroid
 - Oral contraceptive
 - Erythromycin

C/P:

- It ranges from **asymptomatic** mild increase in s. transaminases up to **acute hepatic failure**.
- **Prodroma** of 1-2 weeks duration is present as fatigue, malaise, low grade fever, nausea and vomiting.
 - Then \pm **Jaundice** lasting 2-12 weeks with dark urine.
 - **Acute encephalopathy:**
 - It occurs in acute fulminating hepatic failure.
 - There is **cerebral edema and increased ICP**.
 - It occurs because;
 - There is failure of hepatic clearance which causes accumulation of toxins as ammonia and manganese.
 - There is alteration in endogenous neurotransmitters e.g. γ -amino-butyric acid (GABA), glutamate, and nitric oxide.
 - There is absence of enzymes of the urea cycle in the brain which results in glutamine accumulation (this is a substrate for the urea cycle). It is an osmotic compound leading to cerebral edema (only in acute liver failure). In chronic liver failure, glutamine accumulates but compensatory changes prevent edema formation.
 - **Complete recovery** (s. transaminases return to normal) within 4 months.
 - **Complications** (especially after B and C infections).
 - a) **Chronic active hepatitis:** 3-10 % after B and ≥ 50 after C.
 - b) **Chronic infectious carrier:** 0.3-30% after B and 0.5-1 % after C.
 - In B; infectious carriers are detected by persistent HBs Ag.
 - In C; infectious carriers are detected by hepatitis C viral RNA in peripheral blood by polymerase chain reaction (PCR).

Anesthetic Management:

Preoperative Management:

- **Postpone all elective surgeries** until resolving of acute hepatitis (indicated by normal liver function tests) as it increases the mortality and morbidity.

ANESTHESIA WITH LIVER DISEASES

Only emergency surgeries should be done during acute hepatitis.

- Assess the **cause and degree** of hepatic impairment e.g. recent drug, alcohol...etc.
- Assess **mental status** as mental changes indicate severe hepatic impairment.

Preoperative Investigations:1- **Hepatitis Markers.**2- **Liver Function Tests:**

- **S. ALT (specific) is generally > s.AST** except in alcoholic hepatitis the reverse occurs.
- **S. Bilirubin and alkaline phosphatase** are usually moderately increased except with the cholestatic type of hepatitis.

3- **PT is increased;** - It is the best indicator for hepatic synthetic function.

- If it is persistent > 3 sec above normal, after vitamin K, this indicates severe hepatic dysfunction.

4- **S. electrolyte and AB gases** cause hypokalemia, metabolic acidosis due to vomiting.5- **S. blood sugar** shows hypoglycemia so, glucose infusion is needed.6- **S. albumin** shows hypoalbuminemia, only if **there is a chronic liver disease or malnutrition.**

So, Correct; - Electrolyte and acid base disturbances.

- Coagulopathies by vitamin K or fresh frozen plasma (FFP).

Premedications:

- **Avoid premedications as they may precipitate hepatic encephalopathy** in patients with severe liver disease.
- Give **benzodiazepines and thiamine** for alcoholic patients with acute withdrawal.

Intraoperative Management:

- Extra-caution is indicated in avoiding contact with blood and body fluids from these patients by gloves, masks, protective wear to eyes and not recapping needles, and vaccination (against B).

- • Patients with **viral hepatitis** are with increased CNS sensitivity to anesthetics so; **decrease the doses.**
- Patients with **chronic alcoholic toxicity** show cross tolerance (resistance) to anesthetics so; **increase the doses.**
- Patients with **acute alcoholic toxicity** show CNS depression so, **decrease the doses.**

Choice of Anesthesiaa. Regional Anesthesia:

It can be used provided that there are : - No coagulopathy.
- No hypotension.

b- General Anesthesia:

- **Induction:** by i.v. agents with **standard doses.**

Because their action is terminated by **redistribution** rather than metabolism or excretion so, **there is no fear of prolonged action**, but **large and repeated doses** should be avoided (especially opioids) as they may be with **prolonged action.**

- **Succinylcholine** is used **safely** without a prolonged response.

Because plasma cholinesterase half life is 14 days so, it is unlikely to be affected in acute liver disease.

- **Maintenance:**

Isoflurane and sevoflurane are of choice because they are with the least effects on HBF.

- Inhalational agents (especially isoflurane) are better than i.v. agents because the latter are dependent on liver metabolism.
- Avoid factors which decrease HBF as hypotension, sympathetic stimulation, and high mean airway pressure during controlled ventilation.

Cirrhosis

Causes:

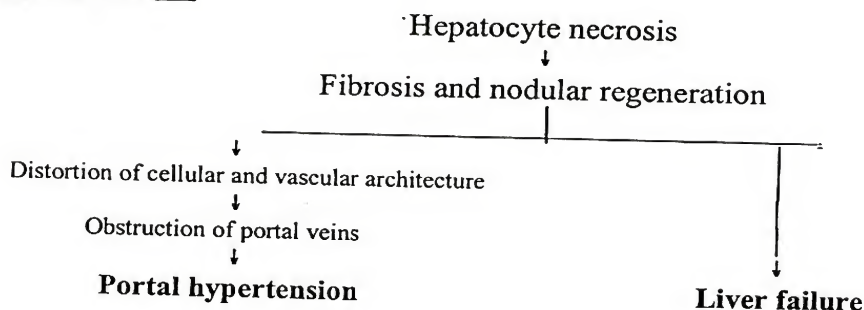
A- Non-Cholestatic Causes:

- **Laennec's cirrhosis** due to alcohol (it is the most common in western countries).
- **Post-necrotic (infectious, toxic, autoimmune) cirrhosis** due to chronic active hepatitis B and C.
- **Cardiac cirrhosis** due to right sided congestive heart failure.
- **Metabolic cirrhosis** due to - Hemochromatosis (deposition of iron in hepatocytes).
- Wilson's disease (deposition of copper in hepatocytes).
- α 1 antitrypsin deficiency.

B- Cholestatic Causes:

- **Biliary cirrhosis** due to chronic biliary inflammation or obstruction e.g. primary biliary cirrhosis or primary sclerosing cholangitis.

Pathophysiology:



C/P of Cirrhosis:

- Signs and symptoms often do not correlate with the disease severity.
- They are absent initially, but jaundice and ascitis eventually develop in most patients.

Preoperative Management:

A) Assess the **cause** of cirrhosis.

B) C/P:

1. GIT System:

A. Portal Hypertension:

- It is defined as; a **pressure gradient > 10 mm Hg** between the portal vein and the IVC (the pressure gradient is 2-6 mm Hg normally).

- C/P: • Extensive porto-systemic venous collaterals producing gastro-esophageal varices, hemorrhoids, around the umbilicus (Caput Medusae) and retro-peritoneally.

- Gastro-esophageal varices cause;
 - Acute massive bleeding which is a major cause of morbidity and mortality.
 - An increased nitrogenous load due to blood breakdown in the intestinal tract. This precipitates hepatic encephalopathy.
- Splenomegaly.

- Preoperative treatment:

1. **Endoscopy** to identify the site of bleeding (to exclude other sites as peptic ulcer or gastritis which need different therapy).

ANESTHESIA WITH LIVER DISEASES

2. Replace blood loss with i.v. fluids and blood products.
3. Vasopressin: either;
 - Localized infusion (0.15-0.20 units/min) by selective arteriography.
 - I.v. infusion (0.3-0.8 units/min).

Avoid high doses as it causes congestive heart failure or heart ischemia (because it leads to coronary VC).

4. Balloon tamponade (Sengstaken-Blakemore, Minnesota, or Linton tubes).
5. Endoscopic sclerotherapy.
6. I.v. nitroglycerin or i.v. propranolol can decrease the portal pressure.
7. If bleeding fails to stop or recurs, emergency surgery is indicated.

B. Assess the Degree of Hepatic Impairment.

This is important to assess the degree of severity and hepatic reserve.

- In the past, patients were classified according to **Child-Pugh classification** to detect the patients who were at low or high risk, to determine the type of surgery needed.

Child-Pugh Classification:

Risk Group		Class A	Class B	Class C
1. Bilirubin	mg/dL	< 2.0	2.0 – 3.0	> 3.0
2. S. albumin	gm/dL	> 3.6	3.0 – 3.6	< 3.0
3. Ascitis		None	Controlled	Poorly controlled
4. Encephalopathy (coma)		None	Minimal	Advanced (coma)
5. Nutrition		Excellent	Good	Poor
6. Mortality rate with surgery	%	2-5	10	50
7. PT	seconds above the control	1-4	4-6	> 6

- Low risk patients can undergo **shunting** procedures.
- Non-selective shunts (portocaval and proximal splenorenal) have been abandoned.
- Selective shunts (distal splenorenal) are the best with less encephalopathy.
- High risk patients can undergo **ablative** surgery (esophageal transection, or gastric devascularization).

These procedures are obsolete nowadays because they hinder liver transplantation later on.

- Recently, **Child-Turcotte-Pugh Scoring System** has used to determine the patients at high risk (those with high score). These patients are scheduled first to have a liver transplantation.

transplantation.				
Points	1	2	3	
1. Bilirubin mg/dL	< 2.0	2.0 – 3.0	> 3.0	
N.B.; For cholestatic liver diseases as primary biliary cirrhosis and primary sclerosing cholangitis, bilirubin values (mg/dL) are substituted by;				
2. S. albumin gm/dL	< 4	4-10	> 10	
3. Ascitis	> 3.6	3.0 – 3.6	< 3.0	
	None	Controlled by diuretics	Poorly controlled despite diuretics	
4. Encephalopathy (coma)	None	Minimal	Advanced (coma)	
5. PT seconds above the control	1-4	4-6	> 6	
Or INR	< 1.7	1.7-2.3	> 2.3	

- Recently, **Trans-Jugular Intra-Hepatic Porto-Systemic Shunt (TIPS) Procedure** is done;

- It is placing an **expandable stent** into the liver parenchyma to provide a porto-systemic communication for treatment of portal hypertension or refractory ascitis.
- It is performed under LA or GA and is often used as a **bridge to liver transplantation**.
- Advantages:

It does not require abdominal operation or vascular division, so, it carries **no technical hazards to the future liver transplantation**, unlike older surgical porto-systemic procedures e.g. spleno-renal shunts.

2. Circulatory System:

- C/P:

1- Hyperdynamic circulatory state:

Due to • A-V shunts in systemic and portal circulation with decreased blood viscosity by anemia leading to a high CO.
• Peripheral VD because vasodilator substances e.g. NO and glucagon will bypass the normal hepatic metabolism.

2- **Alcoholic cardiomyopathy** with congestive heart failure due to alcohol.

3- **Arrhythmias** due to electrolyte and acid base disturbances.

3. Hematologic System:

- C/P:

1. **Anemia** due to blood loss, RBC destruction, BM depression, and nutritional deficiency.

2- **Thrombocytopenia** (and rarely leucopenia) due to congestive splenomegaly (hypersplenism) from portal hypertension.

3- **Coagulation factor deficiencies** due to decreased hepatic synthesis and decreased vitamin K absorption (but fibrinogen and factor VIII are not decreased).

4- **Increased fibrinolysis** due to decreased clearance of tissue plasminogen activators of the fibrinolytic system and decreased levels of antiplasmin.

- Preoperative treatment:

1- **Preoperative transfusion** to increase Hct up to 30% when blood loss is expected during surgery but care against an increase in the nitrogen load should be taken as this precipitates encephalopathy.

2- **Preoperative platelet count** should be done.

3- **Preoperative coagulation screen and thrombo-elastography** can assess the overall clotting and platelet function and fibrinolysis.

Any coagulaopathy should be corrected preoperatively by **FFP**, **platelet** transfusion (if platelet < 100 000/ μ L) and **cryoprecipitate** (in severe cases).

4- Avoid i.m injections for premedications.

4. Respiratory System:

- C/P:

1- **Irr respiratory alkalosis** due to hyperventilation.

2- Hepato-Pulmonary Syndrome:

It is a triad of; • Liver disease.

- Intra-pulmonary vascular dilatation
- Arterial hypoxemia.

Mechanism:

• It is due to **unknown** cause but there may be an increased production and a decreased hepatic clearance of **endogenous vasodilators** e.g. NO.

• **Arterial hypoxemia** is due to;

- Increased pulmonary A-V communications (absolute).
- Increased ventilation/ perfusion mismatching (relative).

C/P of hepato-pulmonary syndrome: Dyspnea, fatigue, cyanosis, and clubbing.

It is **not a contra-indication for liver transplantation**, on the contrary, its **resolution may occur after transplantation**.

3- **Decreased lung volumes** (especially functional residual capacity) due to elevation of the diaphragm by ascitis and pleural effusion (hepatic hydrothorax).

This causes; • Atelectasis.

- **Restrictive lung disease.**

ANESTHESIA WITH LIVER DISEASES- Preoperative treatment:

- 1- Paracentesis to decrease the ascitis.
- 2- Chest X-ray and AB gases to detect hypoxemia and atelectasis.

5. Renal System:- C/P:**1. Decreased renal perfusion.****2. Hepato-Renal Syndrome:**

• **Definition:** It is a functional renal defect (acute renal failure) occurring in patients with preexisting chronic liver failure and without a primary renal disease.

• **Precipitating factors:** GIT bleeding, aggressive diuresis, sepsis or major surgery.

• It is **characterized (and diagnosed)** by;

- Absence of a primary renal disease.
- C/P: Progressive oliguria, azotemia, intractable ascitis, hypovolemia, and high mortality rates.
- Investigations:
 - S. creatinine is > 1.5 mg/dL.
 - Proteinuria.
 - Urinary Na^+ is < 10 mEq/L.
 - Fractional Na^+ excretion is $< 1\%$.

• **Mechanism** of hepato-renal syndrome: It is not clear, but it may be due to;

1. Increased endothelin (and increased sympathetic tone): This causes afferent arteriolar VC
2. Increased NO: This causes efferent arteriolar VD

Both lead to vascular under-filling and renal hypoperfusion causing a decrease in GFR.

• Preoperative treatment: (of hepato-renal syndrome) It is only supportive.

1. **Preoperative hydration** with i.v. infusion for at least 12 hours before surgery.
2. Avoid nephro-toxic drugs e.g. cyclosporine and contrast dyes.
3. **Immediate preoperative mannitol 100 mL** to prevent renal failure. It may be given postoperatively if the UOP is < 50 mL/hr.
4. The only hope is **liver transplantation** if hepato-renal syndrome occurs.
5. In severe renal failure, combined liver-kidney transplantation is needed.

6. Fluid and Electrolyte Balance:- C/P:**1. Ascitis:** Because;

1. **Portal hypertension** increases the hydrostatic pressure which favors transudation of fluid across the bowel.
2. **Hypo-albuminemia** decreases the oncotic pressure.
3. **Seepage of protein rich lymphatic fluid** from the serosal surface of the liver occurs 2ry to distortion and obstruction of lymphatic channels in the liver.

• **Renal Na^+ (and often H_2O) retention.**

2. **Hypoglycemia** may occur.

3. **Electrolyte Disturbances:** as hyponatremia, hypokalemia, hyperkalemia, or hypomagnesemia.

4. Acid-Base Disturbances:

- **Respiratory alkalosis** (the most common): due to hyperventilation.
- **Metabolic alkalosis:** due to loop diuretics, hyper-aldosteronism, vomiting or diarrhea.
- **Metabolic acidosis:** in critically ill patients especially those with renal failure.

- Preoperative treatment:

1. **Judicious preoperative fluid transfusion** as acute i.v. fluid deficits should be corrected with colloid infusions.

2. Avoid preoperative diuresis.

Loop diuretics are only given when the patient is in bed rest.

- Na^+ restriction ($< 2 \text{ gm NaCl/day}$) and spironolactone are ineffective.
- Daily body weight measurements are needed to avoid i.v. volume depletion during diuresis.

3. Treatment of hyponatremia $< 130 \text{ mEq/L}$ is by water restriction.

Treatment of hypokalemia $< 3.5 \text{ mEq/L}$ is by preoperative K^+ replacement.

Treatment of hypoglycemia $< 80 \text{ mg/dL}$ is by dextrose i.v. infusion.

7. CNS:**- C/P: Hepatic Encephalopathy**

- Mental state changes and fluctuating neurological signs as astrexis (flapping tremors), hyper-reflexia, and inverted planter reflex.
- EEG changes as symmetric high voltage slow-wave activity.

N.B.; No cerebral edema occurs due to presence of compensatory changes against the increased osmotic pressure. (Cerebral edema and increased ICP with the possibility of herniation occur only with acute encephalopathy as in fulminating hepatic failure).

- Cause: There is **shunting** of portal blood away from the liver (with liver impairment) directly to the systemic circulation. This allows **substances absorbed from the GIT to bypass metabolism in the liver. Therefore, these substances reach the systemic circulation as ammonia, methionine, metabolites as mercaptans, short chain fatty acids and phenols with an increase in aromatic amino acids and a decrease in branched chain amino acids.** This occurs with increased BBB permeability and increased γ - amino-butyric acid in the brain.

- Precipitating factors:

1. GIT bleeding or increased dietary protein intake.
2. Hypokalemic alkalosis (from vomiting or diuresis).
3. Infections.
4. Bad liver functions.

- Preoperative treatment:

1. Correct precipitating factors.
2. Oral lactulose or neomycin to decrease intestinal ammonia absorption.
3. Avoid premedications in patients with history of encephalopathy as they are sensitive to CNS depressants.
4. Flumazenil (a benzodiazepines antagonist) is tried.

8. Infections:

- Spontaneous bacterial peritonitis may occur.
- Screening for viral hepatitis is needed.

Premedications:

1. **Sedatives:** They are **avoided** in patients with **hepatic encephalopathy**.
2. **Avoid i.m. injections** due to coagulopathy (so use oral or i.v. routes).
3. **Continue preoperative management.**

Intraoperative Management:

Extra-caution is indicated in **avoiding contact** with blood and body fluids from these patients by gloves, masks, protective eye wear and not recapping needles, and vaccination (against B virus).

ANESTHESIA WITH LIVER DISEASES

Aim:

Preservation of the hepatic arterial perfusion as the liver is dependent mainly on it (because the portal venous blood is decreased) so, avoid any decrease in the HBF.

Monitoring:

Standard +

- AB gases.
- Invasive ABP.
- CVP and PCWP.
- UOP if UOP is decreased although fluid replacement so, give: - Mannitol.
- Low dose dopamine.

Choice of Anesthesia:

a) Regional Anesthesia:

It can be used provided that there is:

- No coagulopathy.
- No Hypotension.
- And avoid large doses of amide LAs as they are metabolized in the liver so, they may cause toxicity.

b) General Anesthesia: It is the best.

Generally, the response to anesthetic agents is unpredictable in patients with cirrhosis due to altered protein binding and metabolism.

Induction:

- **Rapid sequence crash induction** with cricoid pressure or **awake intubation**.

Due to:

- Preoperative nausea and vomiting.
- Upper GIT bleeding.
- Abdominal distension from massive ascitis.
- Induction agents:
 - **Thiopentone:** - Its clearance is unchanged because its reduced metabolism is balanced by the decrease in protein binding.
- Cirrhotic patients are CNS sensitive to thiopentone so decrease the dose except in alcoholic patients, there is cross tolerance so increase the dose.
 - **Ketamine:** - If there is hypotension.
 - **Etomidate** is safe.
 - **Suxamethonium:** with prolonged action due to decreased pseudo-cholinesterase (actually, this has no any clinical significant) + if the patient with renal failure so; care of hyperkalemia is taken.

Maintenance:

$O_2 + N_2O + Isoflurane + Opioid + Muscle relaxant$ with IPPV.

- **N_2O :** may be avoided if the patients are with large right to left intra-pulmonary shunts to avoid hypoxia.
- **Isoflurane:** is of choice due to..... in small doses.
Avoid halothane as it may cause confusion if the liver function tests deteriorate postoperatively.
- **Opioids:** - They should be used in small doses to decrease the dose of volatile agents, but they can cause respiratory depression as they are metabolized in the liver (pethidine is better than morphine).

- **Muscle relaxants:**

- **Atracurium** is of choice: its metabolite, laudanosine, may accumulate causing convulsions.
- Muscle relaxants which depend on hepatic metabolism (pancuronium, or vecuronium) require smaller than normal maintenance doses.
- **Controlled ventilation and PEEP** are used to;
- Avoid hypoxia.
- Maintain normal PaCO_2 as hypercapnia decreases HBF, and avoid an increase in ICP if there is encephalopathy.

Intraoperative Fluid Replacement:

- **Aim:** To preserve i.v. volume and UOP to avoid hypotension and renal shutdown.
- There is usually great fluid shifts due to:
 - Venous engorgement from portal hypertension.
 - Coagulopathy.
 - Evacuation of ascitis.
 - Prolonged surgery and adhesions from previous surgeries.
- **Type of fluids:**

1. **I.v glucose:** - To prevent hypoglycemia.

- To decrease the like-hood of deposition of potentially harmful lipid soluble metabolic products of volatile anesthetics in hepatocytes.

N.B.; Intraoperative glucose infusion is needed in;

- Pediatric patients.
- Diabetic patients.
- Hepatic patients.
- Hyponatremia.
- Any patient with documented hypoglycemia.

2. **Colloids:** are better than crystalloids to avoid Na^+ overload.

3. **RBC transfusion** (in anemic patients): Follow rule of 1 unit transfused for each 1 unit blood loss. **Whole blood is preferred** to packed RBCs.

4. **FFP and platelet transfusion:** to correct coagulation factors and platelet deficiencies respectively.

N.B.; I.v. Ca^{++} is often needed to reverse the -ve inotropic effect of the decrease in ionized Ca^{++} in blood due to citrate toxicity (because citrate which is used as anticoagulant in blood units is not metabolized in cirrhotic liver).

Hepato-Biliary Disease

Causes: Decreased bile flow causing cholestasis.

1- Extra-hepatic Obstruction of Biliary Tract (Obstructive Jaundice):

- Due to: - Gallstone - Stricture - Tumors in the common hepatic duct (figure 18-1).
- C/P: - Patients with complete obstruction show progressive jaundice, dark urine, pale stool and pruritis.
 - Cholelithiasis (stone) causes biliary colic and transient jaundice.
 - Cholangitis (ascending infection in biliary system) causes chills and fever.
 - Acute pancreatitis: if a gallstone obstructs the pancreatic duct.
- Treatment: surgical.

2- Intra-hepatic Cholestasis:

- Due to: -Viral hepatitis.
 - Idiosyncratic drug reaction with phenothiazines, and oral contraceptive.
- Treatment: medical.

ANESTHESIA WITH LIVER DISEASES**Investigations:**

- Increase in conjugated bilirubin.
- Increase in s. alkaline phosphatase (moderate to severe).
- U/S, cholangio-grams, radio-isotope, and CT to diagnose extra-hepatic causes.

Preoperative Management:

- It is a controversy to do or delay cholecystectomy during or after the acute attack.
- After resolution of the acute attack, no special management is needed.
- During the acute attack, special preoperative management is needed as:
 1. **Adequate hydration** with i.v. fluids and **mannitol** to decrease the high bilirubin levels (mannitol excretes bilirubin via the kidney) and to avoid postoperative renal failure.
 2. **Naso-gastric suction.**
 3. **Antibiotics.**
 4. **Preoperative correction of PT by:**
 - **Parental vitamin K** needing 24 hours for full response (due to vitamin K deficiency).
 - If it is not corrected so, **FFP** is given.
 5. Long standing extra-hepatic obstruction (> 1 year), causes **2ry biliary cirrhosis and portal hypertension**. They should be investigated and managed.
- Current practices favor early operations in patients who are with high surgical risks and those who fail to improve with medical management.

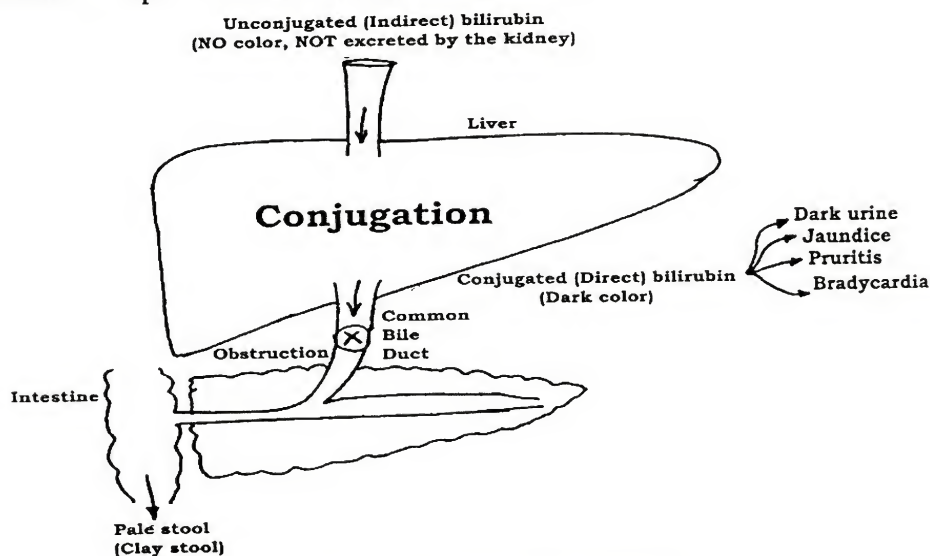


Figure 18-1; Hepato-biliary diseases

Intraoperative Management:

- **Opioids:** They cause spasm of the sphincter of oddi. Theoretically false +ve intraoperative cholangio-grams may occur so better avoided.
- **Avoid drugs dependent on biliary excretion** as they have an increased duration of action.
- **Maintain preoperative diuresis** by i.v. fluids and mannitol with UOP monitor.
- If **laparoscopic cholecystectomy** is needed "see laparoscopic surgery".

Hepatic Surgery

Examples:

- Repair of lacerations.
- Tumor resection.
- Abscess drainage or hydatid cyst excision.
- Liver transplantation.

Anesthetic Problems:

Patients may be with a **cirrhotic liver** so, all its management.....+

1) Blood loss so;

- It needs **multiple large bore i.v. cannulas** with blood warmers.
- It needs **cell saver devices**.
- It needs **rapid infusion devices**.
- **Surgical maneuvers** to limit blood loss from the exposed liver parenchyma by either;
 - **Intermittent clamping of the portal tract** with or without supra- and infra-hepatic IVC clamping.

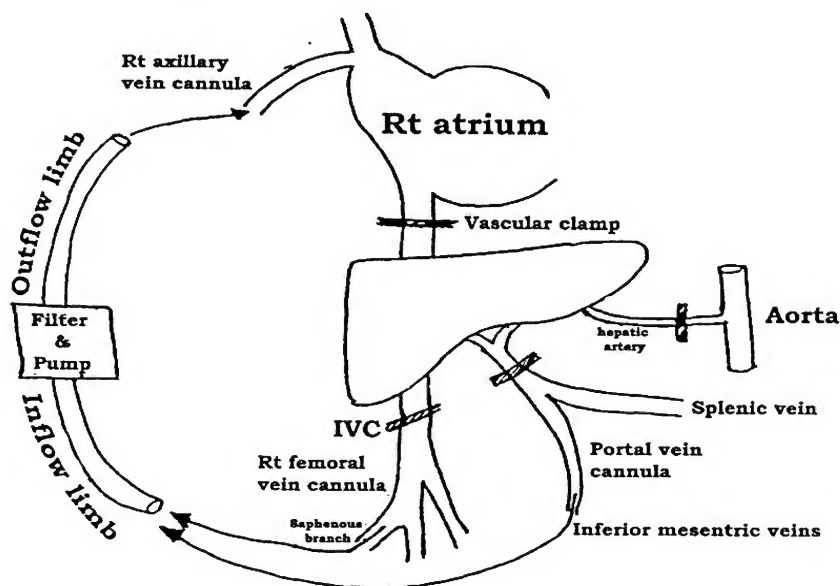


Figure 18-2; Total vascular isolation of the liver and veno-venous bypass

• Total vascular isolation of the liver + cooling of the liver + veno-venous bypass.

Heparin-bonded cannulas are used. One is inserted in the portal vein via inferior mesenteric vein and another cannula is inserted in the right femoral vein via a saphenous branch and both are connected to the inflow limb of the veno-venous bypass. Venous blood is returned to the patient via a cannula inserted in the right axillary vein (figure 18-2).

2) Avoid hypotensive anesthesia.

3) Avoid N₂O due to - Lengthy operations which cause gut distension.

- Fear of air embolism during vascular isolation of the liver.

4) Hypoglycemia may occur after large liver resection.

5) Peritoneal contamination may occur after abscess drainage.

6) Anaphylaxis may occur after hydatid cyst drainage with spillage of echinococcus antigen.

7) Hypothermia.

8) Renal protection in jaundiced patients (i.v. fluid, mannitol, and dopamine).

Hepatic Transplantation

- It is the only curative therapy for hepatic failure. It is from either;
 - **A Cadaver:** The liver can be split to provide grafts for two recipients (usually one adult and one pediatric patient)
 - **A Living close relative:** It is more common nowadays.
- **Orthotopic liver transplantation:**
The recipient's liver is excised and replaced entirely with a donor liver **in the same anatomic position.**
- It is a lengthy operation lasting 6-18 hours (average 8 hours).
- One year survival rate is > 85% in some centers.
5 years survival rate is 50-60%.

Indications of Liver Transplantation

- 1- All causes of liver cirrhosis.....(mention them).
 - 2- Primary liver malignancy (hepato-cellular carcinoma of the liver): Those with;
 - A single tumor smaller than 5 cm in diameter.
 - three or four tumors, the largest of which is smaller than 3 cm in diameter.
 - 3- Fulminant acute hepatic necrosis.
 - 4- Biliary atresia (it is the most common indication for pediatric liver transplantation).
 - 5- Budd-Chiari syndrome.
- N.B.; Hepatic failure after **viral** related infection is **controversial** because:
- There is a high incidence of **re-infection** (near 100%) with hepatitis B and C.
 - Patients with long standing chronic active hepatitis have a 200 fold **increased risk of hepatocellular carcinoma**. The susceptibility of malignancy is increased by immuno-suppression.

Absolute Contraindications

- 1- Positive HIV serology.
- 2- Extra-hepatic malignancy.
- 3- Cholangio-carcinoma.
- 4- Active untreated sepsis.
- 5- Advanced cardio-pulmonary disease.
- 6- Active alcoholism or substance abuse.
- 7- Anatomic abnormalities preventing transplantation.
- 8- Persistence of hypoxia after 100% O₂.
- 9- Unfavorable psychological conditions (e.g. psychiatric illness precluding medication compliance).

Patients' Status on the Liver Transplantation Waiting List

By the **United Network for Organ Sharing (UNOS)** (in 2002)

- **In the past**, they depended on **Child-Turcotte-Pugh scoring system "CTP score"** (see before) as score > 7 was required to list a patient for liver transplantation.
- **Recently**, the adult patient's status on the waiting list is now determined by the **Model for End-Stage Liver Disease (MELD) score**. It is calculated mathematically as follows:
 - MELD formula (score) = $0.957 \times \text{Log}_e (\text{Creatinine mg/dL})$
 $+ 0.378 \times \text{Log}_e (\text{Bilirubin mg/dL})$
 $+ 1.120 \times \text{Log}_e (\text{INR})$
 $+ 0.643$
 - Multiply the score by 10 and round to the nearest whole number.

- Laboratory values < 1.0 are set to 1.0.
- The maximum s. creatinine is considered 4.0 mg/dL in MELD score equation. For patients receiving dialysis s. creatinine is set to 4.0 mg/dL.
- MELD score ranges from **6-40**. Patients with a **higher score** have a greater short term risk of dying from liver disease and are **ranked higher on the liver transport waiting list**.
- **Exceptions** to the MELD score are patients with **fulminant hepatic failure** who have a life expectancy of < 7 days without a liver transplant. These patients are termed **status 1** and are **ranked highest** on the waiting list. This group includes;
 - Patients without a prior history of liver disease who develop hepatic failure.
 - Patients who suffer **primary graft non-function or hepatic artery thrombosis within 7 days** of a liver transplant.
 - Patients with acutely decompensated **Wilson's disease**.

N.B.; For pediatric patients; **Pediatric End-Stage Liver Disease Model (PELD)** score is used. It is similar to MELD, but uses bilirubin, INR, and albumin, and incorporates the child's age and growth failure into the formula.

Anesthetic Management:

Preoperative Management:

- As in liver cirrhosis.....(discuss them in details...).
- Evaluation of anatomic suitability of liver transplantation as weight, height, and chest measurements.
- MRI, duplex, angiography, and U/S are done.
- Other systems.
- Methyl prednisolone and azathioprine are given before the surgery.

Intraoperative Management:

Monitoring: As liver cirrhosis.....+

- **Invasive ABP:** The **radial artery** is preferred over infra-diaphragmatic sites because the abdominal aorta is occasionally cross-clamped during hepatic arterial anastomosis. **2 lines** are inserted in each arm; one for ABP (heparinized) and the other for blood sampling for coagulation study (un-heparinized).
- **CV line:** It is preferred in **veins above the diaphragm** over infra-diaphragmatic sites because supra-hepatic IVC is clamped during the surgery.
- **Serial Hct:** It is needed to guide blood replacement.
- **Oximetric thermodilution pulmonary artery catheter:**
- **ICP monitoring:** the risk of brain herniation is high in patients with a marked increase in ICP as acute encephalopathy in **fulminant hepatic failure**. So; continuous intra-cranial epidural pressure monitoring is recommended in these patients with severe encephalopathy.

Induction: As in liver cirrhosis.....+

- **Suxamethonium:** It is with a prolonged action but safe, because:
 - The surgery is long so, its prolonged action is not detected.
 - Multiple blood transfusions are given. They usually contain cholinesterase enzyme.

Patient Position

The patient lies in the supine position with the right arm abducted at the shoulder and flexed at the elbow. It is fixed by a bandage to a metal stand.

Maintenance: As in liver cirrhosis.....+

- **N₂O** is avoided or used only before perfusion of the donor graft to:

ANESTHESIA WITH LIVER DISEASES

- Avoid marked bowel distension.
- Avoid expansion of venous air embolism if it occurs.
- **Muscle relaxants:** its choice is not important because the patients are routinely left intubated at the end of surgery.
- Measures to **avoid hypothermia** should be taken because the operation is long and there is an increased blood loss.

Intraoperative Complications:

The operation is divided into 3 phases.

I) Pre-Anhepatic (Dissection) Phase: (Phase of Native Hepatectomy)

It begins with a wide subcostal incision. The liver is dissected so that it remains attached only by the IVC, portal vein, hepatic artery and the common bile duct. It ends with clamps over these vessels.

1. Massive Blood Loss: It occurs due to:

- Preoperative coagulopathy and thrombocytopenia.
 - Previous abdominal surgeries.
 - Increased venous collaterals between the portal and systemic venous circulation
- So; 1. Insert 3-5 large **venous cannulas** (14 or larger gauge). Avoid cannulation in the arm to be used for veno-venous bypass.
2. Prepare **multiple blood transfusions** as typically these operations require
- 15-30 units of RBCs.
 - 15-30 units of FFP.
 - 15-30 units of platelets.
 - 10-20 units of cryoprecipitate.

Nowadays, fewer blood transfusions are needed.

3. **Fluid (and blood) warming devices** should be available.
4. **Rapid infusion devices** should be available:
 - They need a 8.5 F specialized catheters in the antecubital veins.
 - They can infuse 2 L/min.
5. **Blood salvaging (saving) devices** should be available.
 - They can decrease the blood needed by 25-30%.
6. **Aprotinin (Trasylol) or E- amino-caproic acid** infusion.
7. **Correction of coagulopathy** with the help of thrombo-elastography or standard laboratory tests (PT, fibrinogen, and platelets transfusion).

2. Renal Protection:

- 1- Adequate i.v. fluid replacement.
- 2- Dopamine (dopaminergic dose): just after induction of GA.
- 3- Mannitol 20% 1 gm/kg i.v. 1 hour before veno-venous bypass.
- 4- Loop diuretics: furosemide 1 mg/kg i.v.
 - They increase renal blood flow.
 - They decrease renal O₂ consumption.
 - They preserve the renal function.

3. Mg Sulfate Infusion:

- 200 mg/hr are given through the preanhepatic, anhepatic, and reperfusion phases to;
- Provide hemodynamic stability.
 - Prevent sympathetic induced ventricular arrhythmias especially during the reperfusion phase.
 - Correct hypomagnesemia caused by citrate infusion.

4. CaCl Infusion:

It is given to correct hypocalcemia due to citrate infusion.

II) Anhepatic Phase:

It begins with clamping of IVC, portal vein, hepatic artery and common bile duct then the liver is excised. Veno-venous bypass may be done and the liver is anastomized. It ends with graft reperfusion.

A- Hemodynamic Effects of Clamping IVC (Supra- and Infra-Hepatic) and Portal Vein:

- On clamping;
 - VR is decreased resulting in a decrease in CO and hypotension proximally.
 - Increased venous pressure occurs resulting in;
 - Increased bleeding.
 - Impaired renal perfusion.
 - Increased edema, splanchnic congestion, and ischemia of the intestine.
- To avoid these problems:

1. Veno-Venous Bypass (Vascular Isolation of the Liver):

- It is done in adults and children > 10 kg BW. Nowadays, it is rarely needed.
- As before, by cannulating IVC (via the saphenous of the right femoral) and portal vein (via the inferior mesenteric vein) then diverting their blood flow (1-3 L/min) away from the liver and back to the heart via the right axillary vein (the pump and the tubes are designed so that they do not need patient heparinization).
- Advantages:
 - It decompresses splanchnic vessels so, it promotes early return of the gut motility.
 - It decompresses renal veins so it decreases acute renal dysfunction.
 - It improves the heart filling.

2. Prophylactic Mannitol or Low Dose Dopamine (2-3 µg/Kg/min):

- They are given before and during venous clamping to preserve renal function, but their values are unproved.

3. Temporary Inotropic Support (+ Blood and Fluids):

- It is needed transiently until an effective veno-venous bypass is established.

B- Metabolic Effects of Anhepatic Phase:

- On removal of the liver;

1. Hypocalcemia:

- Because there is no more metabolism of citrate from blood products, hypocalcemia causes cardiac depression.
- So, CaCl 200-500 mg is given guided by ionized Ca^{++} concentration measurement to avoid hypercalcemia.

2. Metabolic Acidosis:

- Because there is no more clearance of acid metabolites from the intestine and lower body.
- So NaHCO_3 is given guided by AB gases as excessive NaHCO_3 causes hypernatremia and metabolic alkalosis which typically occur after massive blood transfusion (THAM should be considered when large amounts of alkali therapy are needed).

3. Hypoglycemia:

It occurs especially in severe liver disease or fulminant hepatic failure. So, it needs i.v. glucose containing solutions.

Hyperglycemia:

- It is more common due to the large amounts of transfused blood products so, glucose containing solutions are not used except if hypoglycemia is documented.

C- Immuno-Suppressant Therapy:

1. **OKT-3:** It is a monoclonal antibody against the T_3 -locus on human lymphocytes.
2. **Azathioprine:** 200 mg i.v. is also given.

III) Post-Anhepatic Phase (Neo-Hepatic Phase) (Reperfusion of the Liver):

In which revascularization (reassessed by duplex) and biliary reconstruction are established to the new liver with a risk of;

1) Air Embolism:

- As air enters the hepatic sinusoids, pulmonary or systemic paradoxical embolism may occur due to extensive arterio-venous communications.

- To decrease the incidence of air embolism:

1- **Infusion of cold lactated ringer via the portal vein and hepatic artery of the new**

Figure 18-3; Air embolism removal

liver should be done while venous anastomosis

are being constructed. It also removes university of Wisconsin solution.

2- After completion of the portal and supra-hepatic caval anastomosis, but before completion of the infra-hepatic caval anastomosis, **the portal vein clamp is released.**

Therefore, blood from the portal vein flushes out any air remaining in the liver which can now escape through the incomplete infra-hepatic caval anastomotic site (marked hypotension may occur needing inotropes and i.v. fluids), after flushing, venous clamps are reapplied until

infra-hepatic caval anastomosis is completed (figure 18-3).

2) Effects of De-clamping and Reperfusion of Transplanted Liver (Reperfusion Phenomenon):

1. Marked Hypotension and Myocardial Depression:

- Due to the washout of -ve inotropic or vasodilating factors from the previously ischemic tissues.

- Treatment: • It is usually transient. It is treated by CaCl_2 1-4 mg i.v. and NaHCO_3

• If persistent, inotropes are given as dopamine or adrenaline.

They usually control the ABP within 30 min.

N.B.; Do not give i.v. fluids or blood as this causes engorgement of the transplanted liver.

If this occurs nitroglycerine infusion should be used to decompress the engorged liver.

2. Hyperkalemia: S. K^+ usually increases 1-2 mEq/L.

- Due to • K^+ release from any remaining preservative solution.

• Acidosis aggravates the increase in s. K^+ .

- It is treated by CaCl_2 and NaHCO_3 .

3. Hypernatremia: (usually 150-158 mmol/L)

- It can be limited by infusion of hypotonic i.v. fluids after hemodynamic stability.

4. Metabolic Acidosis:

- Due to the release of large acid load from ischemic tissues in the lower body (especially without veno-venous bypass).

- So, prophylactic NaHCO_3 is given.

Therefore, arrhythmias (especially bradyarrhythmias) can occur.

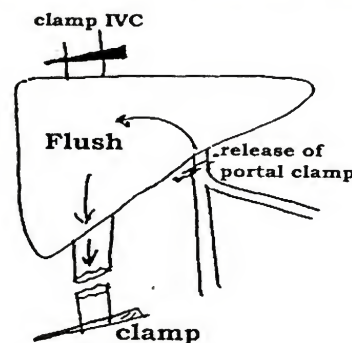
3) Coagulopathy:

- Due to - Thrombocytopenia.

- Decreased coagulation factor levels.

- Fibrinolysis due to the release of tissue plasminogen activator and absence of liver produced plasminogen activator inhibitors.

- So; - Proper coagulation profile is needed.



- Management of appropriate blood components.
- Anti-fibrinolytics as amino-caproic acid 1gm i.v. to inhibit the plasmin action on fibrin.

4) Continue Dopamine and Mg SO₄ Infusion.

5) Prostaglandin E₁ Infusion:

- It starts at 10 µg/hr and is increased to 40 µg/hr after hemodynamic stability after reperfusion of the transplanted liver.
- It increases blood flow to the transplanted liver.

6) Hypothermia:

- It is a major problem during reperfusion. The temperature reaches 34-35°C although the active measures are taken.

7) Neohepatic Function can be estimated by:

1. The Appearance of the Liver:

- It should be good color, not distended, sharp margin, and soft in substance.

2. Enhanced Production of CO₂:

This is due to metabolism of organic acids by the new liver. This is observed by a rise in ET CO₂.

3. Return of Metabolic Functions:

- By improvement of acidosis and development of **metabolic alkalosis**.

But this may not be apparent if there is continuous blood loss after reperfusion of the new liver.

4. Hypokalemia:

- It occurs several hours after reperfusion. It may need K⁺ supplementation.

5. Normalization of Coagulation Factors:

- By measuring PT, PTT, platelet, coagulation factors, fibrinogen factors, V, VII, and VIII (they are continuously measured through all phases of surgery).
- Normalization of coagulation factors takes hours to days after the transplantation to be corrected.

6. Appearance of Bile Production:

7. Measurement of Mono Ethyl Glycine Xyloide (MEGX):

1 mg/Kg xylocaine i.v. is given then MEGX level is determined. If it is > 100 ng/mL, this indicates a good function.

8. S. Transaminase and S. Glucose.

9. Increased UOP: It is very important.

10. Arising Core Temperature.

11. Decreased Ca⁺⁺ Requirement.

Special Situations

A) Transplantation For Fulminant Hepatic Failure:

The same as liver transplantation, but care is taken for **acute encephalopathy**.

- There is cerebral edema and increased ICP which may cause herniation. There is a change of the level of consciousness up to coma.
- It needs preoperative ICU admission.
- It is managed as;
 - Frequent assessment of the mental status.
 - Avoid sedatives which can obscure the neurologic changes.
 - Care of the airway if grade III (stupor) or IV (coma) occur to avoid aspiration which can preclude liver transplantation.
 - Avoid the increase in ICP during intubation.

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- **Monitor ICP.** If the ICP is increased > 25 mm Hg, it should be treated with mannitol.....etc.
- **Monitor cerebral perfusion pressure** by trans-cranial Doppler. It should be above 50 mm Hg.

B) Pediatric Liver Transplantation:

The same as adult liver transplantation, but with the following considerations;

- 1- Indications:
 - **Biliary atresia** (it is the most common cause).
 - **Metabolic liver diseases** (it is the second most common cause).
- 2- Bleeding may be not severe because in biliary atresia, the synthetic function of the liver is preserved causing **good synthesis of coagulation factors**.
- 3- **Hepatic artery thrombosis** is a major risk.

C) Re-Transplantation:**1- Early Re-Transplantation: (within days of the first transplant)**

- It is due to;
 - Primary non-function of the graft.
 - Or • Surgically uncorrectable portal vein thrombosis.
- It is **easier surgically** as the dissection planes are already present, but **difficult medically** as the patient has fulminant hepatic failure.

2- Late Re-Transplantation: (within years of the first transplant)

- It is due to chronic rejection.
- It is difficult surgically as adhesions are present.

D) Living Donor Transplantation:

- It is the most common in Egypt and its rate is increasing in allover the world.

1- Adult-to Adult Transplantation:

Where the right lobe is transplanted.

2- Adult-to Pediatric Transplantation:

Where the left lobe is transplanted.

Postoperative Management:

In ICU usually for 7 days for;

1) Ventilatory Support:

- Routine in all patients so; do not reverse muscle relaxant or stop opioids.
- Weaning occurs when;
 - Coagulopathy is controlled.
 - Neo-hepatic function returns to normal.
 - Renal function is normal.
 - Normothermia.
 - No evidence of complications as sepsis or pulmonary congestion.

2) Assessment of Neo-Hepatic Function: (= Monitor of the graft function)

As before 1 to 7 + diagnosis of rejection is done by **liver biopsy**.

3) Postoperative Immuno-Suppressive Therapy:**1. Cyclosporine:**

- Side effects:
 - Liver toxicity.
 - Renal toxicity.
 - CNS toxicity (confusion, fits, coma).
 - Hypertension.

2- **Corticosteroids:** They are combined with cyclosporine. Their side effects are.....

3- **Azathioprine:** It is combined with cyclosporine. Its side effects are leucopenia, anemia, and thrombocytopenia.

4- **OKT-3:** It is used in steroid-resistant acute rejection. Its side effects are as above...

5. Tacrolimus (FK-506): It is used in cyclosporine resistant acute rejection. Its side effects are as cyclosporine.

4) Postoperative Complications:

1. Iry Non-Function of the Liver:

- It occurs in 7-10% of the transplants.
- It needs **hepatectomy and re-transplantation.**

2. Severe Systemic Infections:

- Due to the use of immuno-suppressive drugs.

3. Respiratory Failure.

4. Renal Failure: due to immuno-suppressants and IVC clamping.

5. Metabolic and Fluid Disturbances: as metabolic alkalosis, hypokalemia, fluid overload, and hyperglycemia.

6. Surgical Complications:

1. Persistent hemorrhage.
2. Bile leak.
3. Stricture or thrombosis of the portal or hepatic vessels.

7. Early Postoperative Death:

- It can occur due to;
 - Thrombosis of the graft vessels so, it should be monitored by U/S doplex.
 - Cholangitis.
 - Air embolism.

8. Coagulation disorders: as DIC and hyper-fibrinolysis.

Anesthesia for Patients With a Transplanted Liver

Generally, the functioning graft (liver) metabolizes drugs in a normal fashion.

Anesthetic Problems:

- 1- **Strict sterile techniques** are very important to avoid infection in these immuno-suppressed patients.
- 2- A **stress dose of corticosteroids** is required for patients on chronic steroid therapy.
- 3- **Cyclosporine and other immuno-suppressive side effects** are investigated and managed: E.g. Renal function should be assessed and managed carefully as cyclosporine is associated with renal impairment.

CHAPTER 19

ANESTHESIA WITH/FOR ENDOCRINE DISEASES

Gland	Hormone	↑ Secretion	↓ Secretion
1) The pancreas	- Insulin	- Insulinoma	- Diabetes mellitus
2) The thyroid	- Thyroxin	- Hyperthyroidism	- Hypothyroidism
3) The parathyroid	- Parathyroid hormone	- Hyper-parathyroidism	- Hypo-parathyroidism
4) The adrenal a- Adrenal cortex: • Zona glomerulosa • Zona fasciculata • Zona reticularis b- Adrenal medulla	30 different corticosteroids are secreted. The most important are: - Aldosterone - Cortisol - Sex steroids (Androgen & estrogen) - Epinephrine (80%) - Norepinephrine & dopamine (20%)	- Mineralocorticoid excess (Conn's syndrome) - Glucocorticoid excess (Cushing's syndrome). - They have no effect on anesthesia. - Catecholamine excess (pheochromocytoma)	- Mineralocorticoid deficiency. - Glucocorticoid deficiency (Addison's syndrome) - Not present as a disease
5) The pituitary a- Anterior pituitary b- Posterior pituitary	- Growth hormone - ACTH - Prolactin - ADH	- Acromegaly or gigantism. - Cushing's syndrome. - Hyper-prolactinemia. - Inappropriate secretion of antidiuretic hormone - Pan-hypopituitarism (for all hormones) - Mono-tropic deficiency (for solitary hormone) - Diabetes insipidus.	
6) Others		- Carcinoid tumor and syndrome. - Multiple endocrine neoplasm.	

Diabetes Mellitus (DM)

Classifications: There is overlapping between the two types;

	Type I (Previously called Insulin Dependent DM "IDDM")	Type II (Previously called Non-Insulin Dependent DM "NIDDM")
- Possible cause	- In a genetically susceptible individual who is exposed to a virus that cause inflammation of the pancreatic islet cells and lymphatic infiltration with subsequent triggering of the autoimmune response leading to destruction of the beta cells. This causes very low insulin production.	- Due to a genetic factor causing; • Skeletal muscle and hepatic resistance to the effects of insulin causing normal or high insulin production. • Relative deficiency of insulin. • Excessive hepatic glucose release.
- Age	- < 16 years (Juvenile onset)	- > 35 years (Maturity onset)
- Onset	- Abrupt	- Gradual
- Associated diseases	- Associated with other autoimmune disease e.g. hypothyroidism, graves' disease, myasthenia grave's, and Addison's disease.	- Not associated with any autoimmune disease.

<ul style="list-style-type: none"> - Body - Complications: <ul style="list-style-type: none"> • Diabetic ketoacidosis • Microangiopathy • Macroangiopathy - Treatment 	<ul style="list-style-type: none"> - Lean <ul style="list-style-type: none"> • Sensitive • Common • Infrequent - Insulin sensitive 	<ul style="list-style-type: none"> - Obese <ul style="list-style-type: none"> • Resistance • Infrequent • Common - Diet, oral hypoglycemic, insulin
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+ **There are other subtypes of type II:**

• **Maturity Onset Diabetes of the Young (MODY):**

- It is heterogeneous group of disorders characterized by non-ketotic DM.
- It represents 1-5% of all diabetes.
- With • Strong family history.
 - Autosomal dominant inheritance.
 - Onset before 25 years old.
 - Symptoms are often present.
 - Non-obese patients.
 - Abnormal beta cell function.

• **Gestational DM:**

- It is the commonest problem during pregnancy.
- It increases the risk of maternal and neonatal complications.
- Thirty to fifty % of the patients get type II DM later on within 20 years after pregnancy.
- It needs insulin for its treatment during pregnancy.

• **Secondary DM:**

- Due to; • Pancreatic disease which decreases insulin release.
 - Drug induced as corticosteroids.
 - Endocrine disease as Cushing syndrome, acromegaly, or pheo.

C/P:

Deficiency of insulin causes hyperglycemia and glucosuria.

These cause 6 Ps + complications.

- Polyuria.
- Polyphagia (i.e. increased eating) + weight loss.
- Pains and muscle weakness.
- Polydipsia (i.e. increased thirst).
- Pruritis (especially at the vulva and anus).
- Premature loosening of teeth.

Diagnosis: by American Diabetes Association.

1- **Symptoms** of DM + **Random plasma glucose** > **200 mg/dL**.

2- **Fasting blood glucose** > **126 mg/dL** (7.0 mmol/L) (normal = 80-120 mg/dL).

3- **Two hours postprandial glucose** > **200 mg/dL** (normal ≤ 160 mg/dL).

4- **Glyco-Hb (Glycosylated Hb) (HbA_{1c}):**

- It is the best measure of overall blood glucose control over the **previous 1-3 weeks**.
- Normally 6 % (5-7%). Its synthesis depends on non-enzymatic glycosylation.
- If high level e.g. 20%, this indicates poorly controlled diabetes over the previous 1-3 weeks.

N.B.; mg/dL = mg % = mg/100 mL

Effect of Anesthesia and Surgery on Insulin and Glucose Metabolism:

A) Anesthesia: (alone)

- Halothane, methoxyflurane, thiopentone or N₂O decrease plasma insulin resulting in an increased glucose level, but they have a very little effect as compared to the stress of surgery.

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- Enflurane, or spinal anesthesia have no effects.

B) Surgery: (also, shock, or sepsis) i.e. any stress:

- This increases catecholamines, adreno-cortico-trophic hormone, cortisol, plasma cAMP and glucose levels i.e. catabolic response during and after surgery.
- No effect on insulin level in the plasma, but there is a relative insulin resistant phase after the surgery.

So; there is an increased insulin requirement acutely in diabetic patients.

Anesthetic Management:

Preoperative Management:

1) Evaluate Blood Glucose Level and Control it "see later".

One third to one half of patients do not know that they are diabetic at the time of surgery.

2) Drug Interactions:

- Thiazides, furosemide, diazoxide, adrenergic drugs (β_2 agonist), corticosteroids, oral contraceptives, and thyroid preparations increase blood glucose level which causes hyperglycemia.
- Hypotensive drugs as β blockers, ganglion blockers and alcohol decreases blood glucose level which causes hypoglycemia (mask its C/P).

So; blood glucose monitoring is essential if one of these drugs are used.

3) Assess Presence of Complications:

A) Chronic Complications:

1- Macro-angiopathy (CVS): especially in type II

- Hypertension, coronary artery disease, peripheral and cerebral vascular diseases.

So, • CVS investigations are essential.

2- Micro-angiopathy: especially in type I

a. **Nephropathy:** up to chronic renal failure.

b. **Retinopathy:** It is associated with cataract, vitreous hemorrhage, and retinal detachment.

3- CNS:

a. **Peripheral Neuropathy:**

- So, • **Avoid local anesthesia** as neurologic deficits may be attributed to the local anesthesia.

b. **Autonomic Neuropathy:**

1- **Painless (silent) heart ischemia** (detected by ECG).

2- **Cardiac arrhythmias** (+ short QT interval).

3- **Orthostatic hypotension** and inability of the heart to compensate for intravascular changes causing C.V.S instability due to sympathetic dysfunction.

4- **Resting tachycardia** and absent variation of HR with deep breathing due to cardiac vagal denervation.

5- **Gastroparesis** causes delayed gastric emptying, vomiting, diarrhea, regurgitation, aspiration and abdominal distension so; premedicate with **metoclopramide** and **rapid sequence induction**.

6- Early satiety.

7- Altered regulation of breathing increases the **susceptibility to depressant drugs**.

8- Lack of sweating or excessive sweating.

9- Neurogenic bladder results in **postoperative urine retention**.

10- Impotence.

4- Stiff Joint Syndrome:

- This is due to non-enzymatic glycosylation of the collagen tissues and proteins (as glyco-Hb).

- It may affect; • The temporo-mandibular joint causing limited mouth opening.
- The atlanto- occipital joint causing limited neck extension.

Both cause difficult laryngoscopy and intubation (30% of type I).

B) Acute Complications:

1- Increased Incidence of Infection (and Delayed Wound Healing):

- This is due to a compromised immune system.
- So, • Strict attention to aseptic techniques.
- Insulin doses should be increased.

2- Diabetic Ketoacidosis:

It is more common with **type I diabetes mellitus**.

- Cause: • Inadequate insulin dosage.
- Increased insulin requirements.
- Precipitating factors:
Infection, trauma, and surgical stress.
- C/P: There is hyperglycemia resulting in hyper-osmolarity with over production of ketone bodies. This causes an early presentation.
- CVS: Signs of **dehydration and hypovolemia** up to prerenal failure and shock.
- CNS: Changes in **sensorium** up to coma (cerebral edema).
- Respiration: - Dyspnea (**Kussmaul's respiration** i.e. deep and rapid) to provide compensatory respiratory alkalosis as a compensation for the metabolic acidosis.
- **Fruity breath** of acetone.
- GIT: More symptoms as abdominal pain, **nausea and vomiting** increase the risk of aspiration.
- Temperature changes: Hypothermia due to acidosis and induced peripheral VD.
- Electrolyte deficits: as hyponatremia, hypokalemia, hypo-phosphatemia, and hypomagnesemia. These ion deficits are to provide electro-neutrality for renally excreted ketoacids
- The mortality rate is 5-10% due to late complications as myocardial infarction, infection, and cerebral edema.
- Investigations:
- AB gases: pH is < 7.25 , s.HCO₃⁻ is < 10 mEq/L.
- Increased Ketone bodies (acids) in the blood > 7 mmol/L.
- Increased s. glucose.
- Decreased s. Na⁺, s. K⁺, s. phosphate and s. Mg⁺⁺.
- Treatment:
- a. Treatment of Dehydration:
- By: i.v. fluids, **usually 3 liters** guided by CVP and UOP.
 - 1st liter in the 1st 30 min.
 - 2nd liter in the next 1 hour.
 - 3rd liter in the next 2 hour.
- By • **0.9% saline (NS)**.
- Or • 0.45% saline if s. Na⁺ > 150 mmol/L (i.e. water loss $>$ Na⁺ loss).
- **Glucose 5%** is added 4 – 6 hours later:
 - If blood glucose becomes < 250 mg% (< 15 mmol/L).
- b. Treatment of Hyperglycemia:
- By regular insulin: **Low dose regimen:** (more accurate) 0.2 unit/Kg (i.e. 20 units) of crystalline insulin i.v. followed by 0.1 – 0.2 unit/kg/hour i.v. infusion (or repeated every hour i.m.) monitored by blood glucose and acetone in the urine (i.e. 0.2 unit/kg i.v. + 0.2 unit/kg/hour).

ANESTHESIA WITH/FOR ENDOCRINE DISEASESc. Treatment of Acidosis : (high anion gap metabolic acidosis).

- Only if arterial pH is < 7.2.
- NaHCO_3 is not routinely given because;
 - It makes the IC acidosis worse.
 - It causes paradoxical CSF acidosis.
 - It causes hypokalemia.
 - It shifts O_2 -Hb dissociation curve to the left.
 - It causes hyper-osmolality.
 - It may cause systemic alkalosis (over correction).
- NaHCO_3 infusions. Dose = $\frac{\text{base deficit}}{2} \times \frac{BW}{3}$ (½ correction) then according to pH

monitoring.

d. Treatment of Hypokalemia: (Some patients show increased s. K^+).

- Due to - Vomiting.
 - Insulin glucose therapy.
- K^+ replacement should not be started except **after correction of acidosis** (because acidosis shifts K^+ from IC to EC space causing normo- or hyperkalemia) so, on correction of acidosis and hyperglycemia, K^+ is shifted from EC to IC space makes the hypokalemia apparent. So, it should be treated by KCl 0.5 mEq/kg/hr provided that UOP is > 1 mL / min.
- e. If cerebral edema occurs, it should be treated by mannitol, hyperventilation, decreased fluid rate.

3- Hyper-Osmolar Hyperglycemic Non-Ketotic Coma:

- It is more common as a postoperative complication. It is more common with type II.
- Due to: Insulin resistance.
- Precipitating factors:
 - Sepsis.
 - Advanced age.
 - Hypothermia during cardiopulmonary bypass.
 - I.v. hyper-alimentation.
 - Pancreatectomy.
 - Postoperative dialysis.
 - Drugs as diuretics.
- C/P: Hyperglycemia (> 600 mg/dL) causing **hyper-osmolality** (> 360 mosm/L). This causes delayed presentation;
 - CVS: Osmotic diuresis causes **more dehydration** (7-10 L), hypovolemia up to **prerenal failure** and shock. There are increased thrombotic events.
 - CNS: It is **more** due to changes in the **cerebral** water balance i.e. brain edema causing mental changes (confusion), fits, focal deficits as hemiplegia and decreased level of consciousness up to coma.
 - Respiration: No Kussmaul's respiration or fruity breath as no acetone.
 - GIT: No symptoms are present
 - Temperature: there is low grade fever due to lack of acidosis induced peripheral VD.
 - Electrolyte deficits: They are less severe because these ions are not required to provide electro-neutrality for renally excreted ketoacids.

Investigations:

- AB gases: Acidosis as pH is < 7.25, s. HCO_3^- is < 10 mEq/L. **Lactic acidosis** is present (increased s. lactate > 6 mmol/ L).
- No acetone or ketone bodies (acids) in the blood or the urine.
- Increased s. glucose.

- Treatment:

- Fluids \pm K⁺.
- Small dose insulin.

Q: Differentiate between diabetic ketoacidosis and non-ketotic coma?

4- Hypoglycemia:

It is a decrease in s. glucose to be less than 50 mg/dL.

- **Due to:**
- Excess insulin relative to carbohydrate intake e.g. preoperative fasting.
 - Long acting oral hypoglycemic agents.

- C/P:

a- Neuro-glycopenic symptoms:

Mental changes from faintness, confusion, irritability, nervousness, fatigue up to convulsions and coma.

b- Adrenergic symptoms due to CA release.

- Diaphoresis.
- Tachycardia, hypertension, arrhythmias, and angina.

Most C/P are masked by general anesthesia so, subarachnoid and epidural anesthesia are preferred due to;

- Allow early detection of hypoglycemia.
- Allow early resumption of oral diet postoperatively.

- Treatment:

- If blood glucose < 100 mg/dL, give dextrose 10 grams (e.g. 20 mL of 50% dextrose). (as each 10 gm dextrose bolus increases blood glucose 30 – 40 mg/dL in 70 kg adult).
- Then give glucose-insulin infusions.

Preoperative Investigations: → can be estimated from above.....

Intraoperative Management:**Aim:**

1) Avoiding hypoglycemia: It is the 1ry goal.

2) Avoiding high hyperglycemia (> 250 mg/dL): It is the 2ry goal.

So, try to maintain s. glucose level between 6 – 10 mmol/L (120 – 180 mg/dL)

N.B.; Attempting to maintain euglycemia is imprudent.

Monitoring:

Standard +

- Frequent blood glucose analysis every 1 hr for type I
every 2 – 3 hr for type II
- Urine glucose is not accurate for perioperative management.

Perioperative management of DM:

Many protocols are used as:

A) Alberti's Recommendation:

	Maturity onset diabetes	Juvenile onset diabetes
Preoperative	1) Check random glucose, urea and electrolytes. • Well controlled patients: - Change long acting oral hypoglycemics (e.g. chlorpropamide) to short acting oral hypoglycemics. (e.g. glipizide or glibenclamide). • Poorly controlled patients: - Change oral hypoglycemic to soluble insulin s.c. tid and delay elective surgery - Or give glucose/insulin infusion for	1) Check random glucose, urea and electrolytes. • Well controlled patients: - Adjust insulin, as soluble insulin s.c. bid + isophane s.c. • Poorly controlled patients: - Change to soluble insulin s.c. tid and delay elective surgery. - Or give glucose/insulin infusion for emergency surgery.

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	<p>emergency surgery.</p> <p>2) On the day of surgery (24 hr preoperative) stop all agents and continue with glucose/insulin infusion according to blood glucose level.</p>	<p>2) On the day of surgery stop all s.c. agents and continue with glucose/insulin infusion according to the blood glucose level.</p>
<p>Intraoperative</p> <p>Each 1 mmol/L nearly equal 18 mg%</p>	<p>- Continue glucose/insulin infusion as the following:</p> <ul style="list-style-type: none"> • Start infusion of 10% glucose (500 mL) + 10 units soluble insulin + 10 mmol KCl to run 4 – 6 hourly on the day of surgery. • Then adjust insulin in the bag according to blood glucose (Sliding scale). <ul style="list-style-type: none"> < 4 mmol/L (< 80 mg %) → no insulin is given. 4 – 6 mmol/L (80 – 120 mg %) → 5 units insulin / 500 mL glucose 10%. 6 – 10 mmol/L (120 – 200 mg %) → 10 units insulin / 500 mL glucose 10%. 10 – 20 mmol/L (200 – 400 mg %) → 15 units insulin / 500 mL glucose 10%. > 20 mmol/L (> 400 mg %) → 20 units insulin / 500 mL glucose 10%. • Adjust K⁺ dosage according to s. K⁺. <ul style="list-style-type: none"> < 3 mmol/L → add 20 mmol KCl on the bag. > 5 mmol/L → omit KCl. 	
<p>Postoperative</p>	<p>1) Recheck blood glucose 2 – 6 hourly and recheck blood urea and electrolyte daily.</p> <p>2) In minor surgeries, restart oral hypoglycemics with the 1st meal so, it is better to put the patient the 1st case on the operation list and just delay the breakfast till recovery from anesthesia.</p> <p>3) In major surgeries,</p> <ul style="list-style-type: none"> - Continue glucose / insulin infusion. - When oral diet is resumed, give soluble insulin s.c. 8 – 12 units tid before each meal. - Restart oral hypoglycemic agents when daily insulin requirements are < 20 unit/day 	<p>1) Recheck blood glucose 2 – 6 hourly and recheck blood urea and electrolyte daily.</p> <p>2) Continue glucose / insulin infusion.</p> <ul style="list-style-type: none"> - When oral diet resumed, give soluble insulin s.c. tid as the preoperative dosage. - Restart the normal regimen when the daily insulin requirements are stable.

Generally, in 70 Kg patient; one unit of regular insulin decreases s. glucose \approx 25-30 mg/dL (1.5 mmol/L).

B) Continuous Infusion: (It is more accurate).

Pre -, Intra - and Postoperative:

- Regular insulin (short acting) dose:

$$\text{Units / hr} = \frac{S.\text{glucose}(\text{mg / dL})}{150}$$

- +• 5% dextrose (D₅W).

Either

- a) Both are given in **one line**:

- Value: if the i.v line is malfunctioning, the patient will not receive insulin or glucose alone.

- E.g. 5 units regular insulin + 500 ml D₅W given at a rate 1.5 mL/kg/hr (i.e. 1 unit/hr/70 kg) or according to the previous formula.

- b) Each one is given in a **separate line**:

- E.g.: 50 units regular insulin in 250 mL N.S in one line (adjust dose as the previous formula) & 5% dextrose in a rate of 1 mL/ Kg/hr in the other line.

- +• Add 15 mEq KCl to each 500 mL dextrose (because glucose / insulin infusion shifts K⁺ form EC to IC space).

N.B.; Generally:

- The previous doses need to be increased in stress, sepsis, hypothermia as there is increase in counter-regulatory hormone (CAs, glucocorticoids, growth hormone, and glucagon) leading to relative insulin resistance.

- Patients controlled on diet may develop starvation ketosis on the morning of surgery, so there is acetone in the urine without glucose (it is treated with i.v glucose).

- Allergic reactions can occur with insulin up to anaphylactic shock.

Non human insulin > human insulin.

NPH or protamine zinc insulin > protamine sulfate insulin.

- Blood transfusion (with increased citrate concentration) and ringer's lactated (Hartmann's) solutions stimulate gluconeogenesis which increases blood glucose (lactate is converted to glucose).

So, there are increased insulin requirements with blood transfusion and ringer lactated solutions should be avoided.

Postoperative Management:**1) Continue Control and Monitoring Blood Glucose:****2) Postoperative Complications:**

All the acute complications can occur postoperatively especially;

- Increased incidence of infection.
- Delayed wound healing.
- Hyper-osmolar hyperglycemic non-ketotic coma.

The Thyroid Gland

Thyroid Function Tests:

	Total T ₄	Resin T ₃ uptake (R T ₃ U)	Free T ₃ index	Free T ₄	T ₃	Reverse T ₃ (r T ₃)	TSH
1. Eu-thyroid	N	N	N	N	N	N	N
2. Hyperthyroid	↑	↑	↑	↑	↑	↑	↓ 1ry ↑ 2ry
3. Hypothyroid	↓	↓	↓	↓	N, ↓	↓	↑ 1ry ↓ 2ry

N.B.; - In hypothyroidism (1ry or 2ry): T₃ may be normal due to peripheral conversion of T₄ to T₃.

- Resin T₃ uptake test: labeled T₄ or labeled T₃ is injected into the patient then the serum which is enriched with labeled T₄ or T₃ is incubated with a resin that binds the free labeled T₄ or T₃. In the patient, labeled T₃ will bind to unoccupied hormone binding sites. If these sites are already occupied by endogenous thyroid hormones e.g. hyperthyroid state, labeled T₃ will be picked up by the resin in a greater amount. T₃ uptake will also be increased when thyroid binding sites are decreased e.g. TBG deficiency.

T₃ uptake will also be decreased in hypothyroidism or increased TBG sites.

Other Thyroid Investigations:**1) Thyroid Scan:**

It demonstrates iodide concentrating capacity of thyroid gland, functioning thyroid gland tissues are rarely malignant.

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2) Ultrasonography:

It discriminates between cystic (rarely malignant) and solid (may be malignant) nodule.

3) Antibodies to thyroid gland components:

It discriminates between Hashimoto's thyroiditis from cancer.

	Hyperthyroidism (Thyrotoxicosis)	Hypothyroidism (Myxedema)
Causes	<ol style="list-style-type: none"> 1. Grave's disease (90%): it is an autoimmune disease where Ig G acts as a TSH like substance that stimulates the thyroid gland causing thyroid hormone secretion. 2. Thyroiditis. 3. Toxic multi-nodular goiter. 4. Toxic (functioning) single nodule (adenoma). 5. TSH secreting pituitary tumors. 6. Over-dosage of thyroid hormone replacement. 	<ol style="list-style-type: none"> a) 1ry hypothyroidism: (95%) <ol style="list-style-type: none"> 1- Thyroid gland destruction: <ul style="list-style-type: none"> • Chronic autoimmune thyroiditis (Hashimoto's thyroiditis) ± other autoimmune diseases e.g. myasthenia gravis, or adrenal insufficiency. • Previous subtotal thyroidectomy. • Previous radio-active iodine therapy • Irradiation of the neck. 2- Thyroid hormone deficiency <ul style="list-style-type: none"> • Antithyroid drugs. • Excess iodine decreases thyroid release. • Dietary iodine deficiency decreases its synthesis. b) 2ry hypothyroidism: <ol style="list-style-type: none"> 1. Hypothalamic dysfunction causes thyrotropin releasing hormone deficiency. 2. Anterior pituitary dysfunction causes thyroid stimulating hormone deficiency.
C/P	<ul style="list-style-type: none"> • Weight loss (+ increased appetite). • Muscle fatigue and weakness. • Diarrhea. • Heat intolerance. • Hyper-active reflexes, nervousness, fine tremors, and insomnia. • CVS: - Sinus tachycardia up to AF. <ul style="list-style-type: none"> - Increased CO which causes hyperdynamic circulation. This causes high CO heart failure (it is resistant to digitalis). - Warm sweaty extremities. • Hyperglycemia. • Goiter (enlarged gland) which; <ul style="list-style-type: none"> - compresses the airway causing respiratory obstruction. - compresses the recurrent laryngeal nerve causing vocal cord paralysis. - compresses the SVC (by retrosternal goiter) causing S.V.C syndrome which leads to edema and dilatation of the collateral veins of upper thorax, face, neck and upper limb with headache and vertigo. • Exophthalmos. • ± other autoimmune disease e.g. adrenal insufficiency, myasthenia gravis, and inappropriate secretion of ADH • Thyroid Storm (Crisis): <ul style="list-style-type: none"> - Cause: Sudden (acute) release of thyroid hormones into the circulation (not due to the absolute high levels of thyroid hormone). - Precipitating factors: <ol style="list-style-type: none"> 1. Thyroid surgery. 2. Vigorous thyroid manipulation. 3. Withdrawal of antithyroid drug therapy. 4. Radioiodine therapy. 5. Iodinated contrast dyes. 6. Non-thyroid illness as, non-thyroid surgery, 	<ul style="list-style-type: none"> • Weight gain and large tongue. • Muscle fatigue and weakness. • Constipation. • Cold intolerance. • Hypo-active reflexes, depression, and dull facial expressions. • CVS: - Sinus bradycardia and arrhythmias. <ul style="list-style-type: none"> - Decreased CO and cardiomyopathy causing CHF. - Cold mottled extremities (due to peripheral VC). • Hypoglycemia. • Pleural and pericardial effusion. • ± other autoimmune disease e.g. adrenal insufficiency, myasthenia gravis, and inappropriate secretion of ADH. <p>N.B.; If hypothyroidism occurs early in life, mental and physical retardation occur and this is called cretinism).</p> • Myxedema Coma: <ul style="list-style-type: none"> - Cause: Extreme hypothyroidism. - Precipitating factors: <ol style="list-style-type: none"> 1. Surgery. 2. Infection. 3. Trauma. 4. Exposure to cold especially in the elderly. - C/P: <ul style="list-style-type: none"> • Severe muscle weakness. • Hypothermia (< 35°C).

	<p>infection, cerebrovascular accident, CHF, pulmonary embolism, pregnancy, labor, trauma, and diabetic ketoacidosis.</p> <ul style="list-style-type: none"> - C/P: They usually occur 6 – 24 hrs postoperatively with; • Severe muscle weakness. • Hyperthermia. • Altered consciousness, agitation, delirium, and coma. • Tachycardia, hypotension, and CHF. • Dehydration. - <u>Differential Diagnosis:</u> <ol style="list-style-type: none"> 1) Malignant hyperthermia. 2) Pheochromocytoma. 3) Carcinoid crisis. 	<ul style="list-style-type: none"> • Impaired mentation. • CHF. • Hyponatremia due to inappropriate secretion of ADH. • Hypoventilation.
Investigation	Abnormal thyroid function tests ...see above.	Abnormal thyroid function tests .see above
Treatment	<p>A) Treatment of Thyrotoxicosis:</p> <ol style="list-style-type: none"> 1. Drugs inhibiting hormone synthesis: Propyl thiouracil, methimazole and carbimazole. 2. Drugs preventing hormone release (in 24 hrs) and decreasing vascularity of the gland (in 10 days): K⁺ or Na⁺ iodide. 3. Drugs masking signs of adrenergic over-activity: Propranolol (also it inhibits peripheral conversion of T₄ – T₃). 4. Drugs destroying thyroid cell function: Radio-active iodine. 5. Surgery: Sub-total thyroidectomy. <p>B) Treatment of Thyroid Storm: (Aggressive treatment + monitoring).</p> <ol style="list-style-type: none"> 1. Hydration + treatment of precipitating factors. 2. Cooling by cold fluids, cold lavage of body cavities, cooling blankets, ice packs, low ambient temperature (avoid aspirin as it displaces T₄ from its protein binding sites increasing free T₄. Use paracetamol instead). 3. Propyl-thiouracil 250 mg/6 hrs orally or via nasogastric tube. 4. Na⁺ iodide 1 gm. i.v over 12 hrs. 5. Propranolol 0.5 mg i.v increments till HR becomes < 100 /min. 6. Cortisol 100-200 mg /8 hrs i.v. <p>Dexamethazone inhibits peripheral conversion of T₄ to T₃.</p>	<p>A) Treatment of Myxedema:</p> <p>Oral replacement of thyroid hormone (L-thyroxin). Start with 50 µg/day then increase the dose up to 150-200 µg/day over several weeks.</p> <p>B) Treatment of Myxedematous Coma:</p> <ol style="list-style-type: none"> 1- Thyroid hormone i.v. • Loading dose: 300 – 500 µg of levo-thyroxin in patients without heart disease. • Maintenance: 50-200 µg infusion / day - Contraindications: <ul style="list-style-type: none"> • Elderly. • Ischemic heart disease. <p>Or L-tri-iodo-thyroxin 25-50 µg bolus followed by infusion. It has a rapid onset</p> <ul style="list-style-type: none"> - ECG monitoring is essential <ol style="list-style-type: none"> 2- Hydrocortisone 100 mg / 8 hr i.v. 3- Digitalis for CHF but it is usually not given because the hypothyroid heart can not easily perform increased myocardial contractility power. 4- Ventilatory support may be needed. 5- Hydration with D5W and correct electrolyte and temperature disturbances
Anesthetic problems	<ol style="list-style-type: none"> 1) From C/P. 2) Patient preparation. 3) Patient position. 4) Intraoperative complications. 5) Postoperative complications. 	<ol style="list-style-type: none"> 1) From C/P. 2) Patient preparation. 3) ↓ drug metabolism. 4) Delayed recovery.
Preoperative management	<p>1) Make the Patient Euthyroid:</p> <p>a) Elective Surgeries: (including sub-total thyroidectomy).</p> <ul style="list-style-type: none"> - Postpone till the patient becomes euthyroid by: 1- <u>Slow Approach</u> (within 6 – 8 weeks). • Propyl thiouracil 100 mg t.d.s orally then decrease the dose after 6 weeks to 50 mg t.d.s orally. • Carbimazole 20 mg t.d.s orally then decrease the dose after 6 weeks to 10 mg t.d.s orally. * Followed by K⁺ iodide tablet 60 mg t.d.s for 10 days to decrease gland vascularity (if euthyroid state is not reached Ist, K⁺ iodide will act as substrate for synthesis of new thyroid hormone). 	<p>1) Make the Patient Euthyroid:</p> <ul style="list-style-type: none"> - Ideally, patients should be euthyroid but, mild to moderate hypothyroidism is not an absolute contraindication for elective surgery as there is no increased risk or perioperative morbidity or mortality. E.g. hypothyroid patients with symptomatic coronary arterial disease may benefit from delaying in the thyroid therapy until after CABG surgery. <p>a) Elective Surgeries:</p> <ul style="list-style-type: none"> - Postponed if the patient is with severe hypothyroidism or with myxedematous coma.

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	<p>2- <u>Rapid Approach</u> (within 2 weeks).</p> <ul style="list-style-type: none"> • β blockers: - Propranolol 160-480 mg/day tablets (40-120 mg/ 6 hrs) for 2 weeks preoperatively and then followed by 7-10 days postoperatively (it is given every 6 hrs due to increased metabolism). Or - Nadolol (long acting) 160 mg once / day. + • Lugol's iodine (iodine 5% in 10% K^+ iodide) 10 drops orally / 6 – 8 hrs. Or K^+ iodide tablets 60 mg/ 8 hrs. <p>b) Emergency Surgeries: (within 1 hr).</p> <p>There is an increased risk of postoperative thyroid crisis.</p> <ul style="list-style-type: none"> • Propranolol i.v. (1/10 oral dose). • Esmolol 100 – 300 μg / kg / min (it does not prevent peripheral conversion of T_4 to T_3). • K^+ iodide 1 gm i.v. or oral 5 drops / 6 hrs. • Hydrocortisone 100 mg / 6 hrs i.v. or dexamethazone 2 mg / 6 hrs i.v. (to prevent peripheral conversion of T_4 to T_3). <p>- Assess patient's euthyroid state by;</p> <ul style="list-style-type: none"> * Thyroid function tests. * Disappearance of C/P e.g. tremors, and anxiety. * Resting heart rate < 85 beat / min. <p>2) Assess Airway by;</p> <ul style="list-style-type: none"> - Preoperative indirect laryngoscopy to assess vocal cords. - Preoperative X- ray neck, CT scan and flow volume loop analysis to assess airway obstruction (see respiratory anesthesia.....). <p>3) Assess Coexisting Heart Disease.</p> <p>4) Premedication:</p> <ul style="list-style-type: none"> - Sedatives: Increase the dose because; • There is an increased anxiety. • There is increased distribution and metabolism. E.g.; - Oral diazepam 10-20 mg. - Oral clonidine 3-5 μg / kg. - Anticholinergics: are avoided because • There is tachycardia. • They interfere with the body's normal heat regulatory mechanisms. - Anti-thyroid drugs and β blockers are continued till the morning of surgery and postoperatively. 	<p>- Preoperative thyroid hormone is taken orally till euthyroid states are reached.</p> <p>b) Emergency Surgeries:</p> <ul style="list-style-type: none"> - Preoperative thyroid hormone is taken i.v..... see treatment of myxedema coma. <p>- Assess patient's euthyroid state by;</p> <ul style="list-style-type: none"> * Thyroid function tests especially TSH. * Disappearance of C/P. <p>2) Assess Airway as;</p> <p>Large tongue may cause difficult airway management.</p> <p>3) Assess Coexisting Heart Diseases.</p> <p>4) Premedication:</p> <ul style="list-style-type: none"> - Sedatives: Decrease the dose because; • Patients are calm. • There is a decreased distribution and metabolism. • To avoid respiratory depression. - Anticholinergics: are recommended because: • There is bradycardia. - Thyroid hormone: should be continued till the morning of surgery. - Metoclopramide and H_2 blockers to guard against aspiration.
<p>Intraoperative management</p> <p>- Choice of anesthesia</p>	<p>Monitoring: Standard +</p> <ul style="list-style-type: none"> • CVS according to the patient's condition. • Body temperature. <p>A) Regional Anesthesia:</p> <ul style="list-style-type: none"> - Good sedation is needed. - Value: It blocks the associated increased sympathetic activity provided that LA solutions do not contain adrenaline. <p>B) General Anesthesia:</p> <p>Induction:</p> <ul style="list-style-type: none"> • Avoid pressor response of intubation by..... • Thiopentone (it is of choice): <p>It has anti-thyroid action due to its thiourea structure, only at high doses (not the usual doses). Ketamine is avoided as it stimulates sympathetic system which increases HR and ABP).</p> <p>Intubation:</p> <p>Use smaller sized armored E.T.T.</p> <ul style="list-style-type: none"> * As goiter may cause tracheal compression. * It should be placed beyond the thyroid gland in the trachea to avoid tracheal compression during 	<p>Monitoring: Standard +</p> <ul style="list-style-type: none"> • CVS according to the patient's condition. • Body temperature. <p>A) Regional Anesthesia:</p> <ul style="list-style-type: none"> - Proper i.v. fluid replacement is needed. - Decrease the dose of LAs especially amid type due to the decreased metabolism which increases the risk of toxicity. <p>B) General Anesthesia:</p> <p>Induction:</p> <ul style="list-style-type: none"> • Ketamine (of choice) because hypothyroid patients are more susceptible to the hypotensive effects of other anesthetic agents due to: * The decreased CO. * The blunted baroreceptor reflex. * The decreased intravascular volume. <p>Intubation:</p> <p>It may be difficult due to the large tongue.</p>

	<p>surgery. Either awake or inhalational induction is done if airway obstruction is suspected.</p> <p>Maintenance: O₂/N₂O + isoflurane + opioid + muscle relaxant.</p> <ul style="list-style-type: none"> • Volatile agents: <ul style="list-style-type: none"> - Isoflurane is of choice because it does not sensitize the heart to CAs. - There is more risk of hepato-toxicity (of halothane) and nephro-toxicity (of enflurane and sevoflurane) due to increased drug metabolism. - Although clinical impression shows that increased MAC is needed (but not proved) due to: <ul style="list-style-type: none"> * Increased drug metabolism. * Increased CO causes an increase in drug uptake which decreases the alveolar partial pressure. So increasing the inspired concentration of the volatile agents is needed. • Muscle relaxants: are used cautiously. <ul style="list-style-type: none"> - Due to the increased incidence of myopathies and myasthenia gravis so, decrease the initial dose and use a peripheral nerve stimulator. - Pancuronium is avoided as it stimulates the sympathetic system increasing HR and ABP. - Use glycopyrrolate (instead of atropine) to reverse the muscle relaxant. <p>Intraoperative Problems:</p> <ol style="list-style-type: none"> 1- Methods to decrease the body temperature e.g. cooling mattress, cold i.v fluids..... 2- Intraoperative hypotension: It is treated by direct sympathomimetics e.g. phenylephrine or epinephrine (avoid indirect sympathomimetics e.g. ephedrine as they increase CAs in the hyperthyroid patient who has an increased response to CAs). 3- Intraoperative tachycardia and arrhythmia: They are treated by propranolol i.v. or esmolol infusion. 4- Intraoperative thyroid storm see above..... 5- Increased risk of corneal abrasion due to exophthalmos so, the eyes should be protected. 6- Venous air embolism in thyroidectomy as the head is elevated 15-20 degrees to aid venous drainage and decrease blood loss. <p>Extubation:</p> <ul style="list-style-type: none"> - Deep to allow assessment of the vocal cords and airway by direct laryngoscopy or fiberoptic bronchoscopy. 	<p>Maintenance: O₂/N₂O + short acting opioid or benzodiazepines or ketamine.</p> <ul style="list-style-type: none"> • Volatile agents: <ul style="list-style-type: none"> - They are avoided because it produces severe cardiac depression and severe hypotension due to VD and blunted baroreceptor reflex. - Although clinical impression shows decreased MAC is needed (but actually not occur) due to; <ul style="list-style-type: none"> * Decreased drug metabolism. * Decreased CO causes decrease in drug uptake from the alveoli which increases alveolar partial pressure resulting in rapid induction. • Muscle relaxants: are used cautiously. <ul style="list-style-type: none"> - Due to the increased incidence of myopathies and myasthenia gravis so decrease the initial dose and use a peripheral nerve stimulator. - Pancuronium: is recommended. - Use atropine (instead of glycopyrrolate to reverse the muscle relaxant). <p>Intraoperative Problems:</p> <ol style="list-style-type: none"> 1- Methods to increase body temperature e.g. warming mattress, warm i.v fluids..... 2- Intraoperative hypotension It is treated by i.v. fluids and sympathomimetics e.g. ephedrine (avoid phenylephrine which is an α agonist causing severe VC and increasing the afterload on the heart. This results in CHF). <p>Refractory hypotension may be due to:</p> <ul style="list-style-type: none"> * Coexisting 1ry adrenal insufficiency. * Presence of CHF. <ol style="list-style-type: none"> 3- Intraoperative hypoglycemia.
Postoperative management	<p>Postoperative Complications:</p> <ol style="list-style-type: none"> 1- Thyroid storm (crisis): It occurs most commonly 6-24 hrs postoperatively. 2- Recurrent hyperthyroidism or iatrogenic hypothyroidism. 3- Surgical complications: <ul style="list-style-type: none"> a. Recurrent laryngeal nerve palsy: <ul style="list-style-type: none"> - Usually due to surgical edema. - It either; <ul style="list-style-type: none"> • affects the abductor fibers (more common) <ul style="list-style-type: none"> • If unilateral, hoarseness of voice occurs. • If bilateral, aphonia and stridor on inspiration occur. • affects the adductor fibers (rare). This increases pulmonary aspiration. 	<ol style="list-style-type: none"> 1- Delayed recovery may occur due to <ul style="list-style-type: none"> - Slow drug metabolism. - Hypothermia. - Respiratory depression which needs mechanical ventilation. 2- Postoperative analgesia Avoid opioids due to respiratory depression.

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	<p>- So, assess the vocal cords by laryngoscopy immediately after deep extubation. Failure of one or both cords to move may require reintubation and exploration of the wound.</p> <p>b. Hematoma formation:</p> <p>- It may compress the airway (with normal vocal cords). So, this needs immediate wound exploration and clot evacuation.</p> <p>c. Tracheomalacia:</p> <p>- Due to weakening of the tracheal rings by chronic pressure from the goiter. So, on removal of the goiter, collapse of the trachea occurs.</p> <p>d. Pneumothorax: It causes respiratory distress, if surgical dissection is carried down to the mediastinum.</p> <p>e. Hypo-parathyroidism:</p> <p>- Due to un-intentional removal of the parathyroid glands. This causes acute hypocalcemia within 24 - 72 hrs. When s. Ca^{++} becomes $< 7 \text{ mg\%}$, tetany occurs (with inspiratory stridor, and laryngospasm).</p> <p>- It is treated by Ca^{++} gluconate 10% 10-30mL slowly then oral Ca^{++} therapy.</p>	
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Q: What are the causes of postoperative respiratory distress in hyperthyroidism?

The Parathyroid Gland

Hypocalcemia stimulates the release of parathyroid hormone (PTH). This increases s. Ca^{++} to normal.

Hypercalcemia inhibits the release of PTH. This decreases s. Ca^{++} to normal.

I.e. PTH maintains normal s. Ca^{++} level by affecting Ca^{++} movement via GIT, kidneys and bones.

	Hyper-parathyroidism	Hypo-parathyroidism
Causes	<p>1) 1ry hyper-parathyroidism: (s. Ca^{++} is increased).</p> <ul style="list-style-type: none"> * Adenoma 90%. * Hyperplasia. * Carcinoma. <p>2) 2ry hyper-parathyroidism: (s. Ca^{++} is normal).</p> <ul style="list-style-type: none"> * Adaptive response to hypocalcemia produced by - Renal failure. - Intestinal malabsorption syndrome. <p>3) Ectopic (pseudo) hyper-parathyroidism: PTH like substances are released from carcinoma of the liver, lung, breast, and pancreas.</p> <p>N.B.; Other Causes of Hypercalcemia:</p> <ol style="list-style-type: none"> 1) Bone secondaries. 2) Vitamin D toxicity. 3) Sarcoidosis or tuberculosis. 4) Prolonged immobilization. 5) Milk alkali syndrome. 6) Malignancy and chronic inflammation. 	<p>1) Decreased or absent PTH.</p> <ul style="list-style-type: none"> * Accidental removal during thyroidectomy * Parathyroidectomy to treat hyperplasia. * Idiopathic (Di George syndrome) (It is a congenital thymic and parathyroid hypoplasia). <p>2) Resistance to PTH: (although PTH is normal)</p> <ul style="list-style-type: none"> * Congenital pseudo-hypo-parathyroidism as the kidneys do not respond to PTH. * Acquired: <ul style="list-style-type: none"> - Hypomagnesemia and hyperphosphatemia - Chronic renal failure. - Malabsorption vitamin D deficiency. - Chronic use of phenytoin. * Idiopathic during: <ul style="list-style-type: none"> - Osteoblastic secondaries. - Acute pancreatitis. <p>N.B.; Other Causes of Hypocalcemia: = The same causes of resistance to PTH.</p>
C/P	<p>- Due to hypercalcemia:</p> <p>1) CNS: Personality and mental changes (delirium, psychosis, and coma).</p> <p>2) CVS:</p> <ul style="list-style-type: none"> * Hypertension and ventricular arrhythmias * ECG changes (prolonged PR interval and 	<p>- Due to hypocalcemia:</p> <p>a. Acute hypocalcemia:</p> <p>CNS:</p> <ul style="list-style-type: none"> * Laryngospasm, inspiratory stridor, seizures, and tetany. <p>* Chvostek's sign: painful twitching of</p>

	<p>shortened QT interval).</p> <p>3) Eye:</p> <ul style="list-style-type: none"> * Calcification (band keratopathy). * Conjunctivitis. <p>4) Musculo-skeletal:</p> <ul style="list-style-type: none"> * Muscle weakness. * Osteoporosis and otitis fibrosa cystica causing pathological fractures. <p>5) Renal:</p> <ul style="list-style-type: none"> * Impaired renal concentrating ability causing polyuria, polydipsia, and dehydration. * Hyperchloremic metabolic acidosis. * Renal stones. * Renal impairment up to renal failure. <p>6) GIT:</p> <ul style="list-style-type: none"> * Ileus, nausea, vomiting, increased gastric acid secretions (causing peptic ulcers) and pancreatitis. 	<p>facial muscles after tapping over the facial nerve.</p> <ul style="list-style-type: none"> * Trousseau's sign: Carpo-pedal spasm after tourniquet inflation above systolic BP for 3 min. * Peri-oral parasthesia. <p>b. Chronic hypocalcemia:</p> <p>1) CNS:</p> <p>Mental changes as dementia, depression and psychosis.</p> <p>2) CVS:</p> <ul style="list-style-type: none"> * Hypotension, and CHF. * ECG changes (prolonged QT interval, but normal PR interval). <p>3) Eye: Cataract.</p> <p>4) Musculo-skeletal:</p> <p>Neuro-muscular irritability, twitches, muscle cramps and weakness.</p>
Anesthetic problems	<p>1) From C/P.</p> <p>2) S.Ca⁺⁺ should be decreased by</p>	<p>1) From C/P.</p> <p>2) S.Ca⁺⁺ should be increased by</p>
Preoperative management	<p>1) Assess C/P and manage them e.g. hypertension, arrhythmias, renal failure, and dehydration.</p> <p>2) Decrease s. Ca⁺⁺ level by:</p> <ul style="list-style-type: none"> * Hydration with normal saline (150 ml/hr) + diuresis with furosemide (1-2 mg/kg i.v.) (avoid thiazide diuretics as they increase Ca⁺⁺ level). * Plicamycin, glucocorticoids, calcitonin, hemodialysisare rarely used. <p>3) Premedications:</p> <p>Sedatives: Their doses are decreased due to CNS changes.</p>	<p>1) Assess C/P and manage them e.g. inspiratory stridor, hypotension, and CHF.</p> <p>2) Increase s.Ca⁺⁺ level by:</p> <ul style="list-style-type: none"> * I.v. Ca⁺⁺ gluconate 10% 10mL in acute cases. * Oral Ca⁺⁺ + vitamin D in chronic. * Thiazide diuretics increase Ca⁺⁺ level. * Exogenous PTH replacement is not yet practical for clinical use. <p>3) Premedication:</p> <p>Sedatives: Their doses are decreased due to CNS changes.</p>
Intraoperative management	<ul style="list-style-type: none"> * Avoid ketamine due to hypertension and personality changes. * Precautions of renal failure and hypertension. * Avoid hypoventilation as it causes acidosis which increases the ionized Ca⁺⁺. * Use muscle relaxants cautiously due to their unpredictable response as increased Ca⁺⁺ causes muscle weakness. * Osteoporosis which may cause; <ul style="list-style-type: none"> - Vertebral compression during laryngoscopy. - Bone fracture during positioning or transport. * Postoperative hypocalcemic tetany may occur. 	<ul style="list-style-type: none"> * Avoid anesthetics which depress the heart. * Precautions of CHF are taken if it is present. * Avoid hyperventilation (or NaHCO₃ therapy) as it causes alkalosis which decreases the ionized Ca⁺⁺. * Use muscle relaxants cautiously as there is an increased sensitivity. * Citrate containing blood products should be given slowly in patients with preexisting hypocalcemia. * Avoid 5% albumin solutions which may bind and decrease ionized Ca⁺⁺. * Increased risk of coagulopathy (as Ca⁺⁺ is needed for coagulation cascade).

The Adrenal Gland

	Mineralo-corticoid Excess (Hyper-Aldosteronism)	Mineralo-corticoid Deficiency (Hypo-Aldosteronism)
Causes	<p>1) 1ry hyper-aldosteronism (Conn's syndrome) e.g. *Adenoma *Hyperplasia *Carcinoma (with low renin level)</p> <p>2) 2ry hyper-aldosteronism: There is increased renin angiotensin with increased aldosterone secretion. e.g. *CHF.</p>	<p>1) Atrophy or destruction of both adrenal glands: It causes combined mineralo-corticoid and glucocorticoid deficiency (Addison's disease).</p> <p>2) Isolated mineralo-corticoid deficiency:</p> <ul style="list-style-type: none"> * Unilateral adrenalectomy. * DM. * Heparin therapy.

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	<ul style="list-style-type: none"> *Liver cirrhosis (+ascitis). *Nephrotic syndrome. *Renal artery stenosis. 	<ul style="list-style-type: none"> * Congenital. * Hypo-reninemia due to a defect in juxta-glomerular apparatus or treatment with ACEIs. * Indomethacin causes PGs deficiency.
C/P	<ol style="list-style-type: none"> 1) Hypertension (due to hypervolemia) which may cause CHF. 2) Metabolic alkalosis which decreases s. ionized Ca^{++} resulting in tetany. 3) Hypokalemia which causes muscle weakness. If it is prolonged, hypokalemic nephropathy (with polyuria) occurs. 4) Hypernatremia: slightly or even normal. 	<ol style="list-style-type: none"> 1) Hypotension (due to hypovolemia) which may cause shock. 2) Metabolic acidosis which increases s. ionized Ca^{++}. 3) Hyperkalemia which causes heart block (any increase in s. K^+ without renal impairment is suggestion for hypo-aldosteronism). 4) Hyponatremia.
Anesthetic management	<ol style="list-style-type: none"> 1) From C/P and causes: E.g. * Manage hypertension, CHF and volume state. * Correct fluid and electrolyte imbalance. K^+ syrup 2-6 gm/day orally for hypokalemia. 2) Spironolactone: It is; * Aldosterone antagonist. * K^+ sparing diuretics. * Antihypertensive. 	<ol style="list-style-type: none"> 1) From C/P and causes: E.g. * Manage hypotension and shock. * Correct fluid and electrolyte imbalance. As this increases Na^+ intake. 2) Exogenous mineralo-corticoid * Fludro-cortisone 0.1- 0.3 mg/day.

N.B.; Aldosterone increases Na^+ and H_2O retention.
and increases H^+ and K^+ excretion.

	Glucocorticoid Excess (Cushing's Syndrome) (Hyper-Adrenocorticism)	Glucocorticoid Deficiency (Hypo-Adrenocorticism)
Causes	<ol style="list-style-type: none"> 1) Exogenous administration of steroid hormones or adreno-cortico-tropic hormone (ACTH). 2) 1ry: Intrinsic hyper-function of adrenal cortex e.g. adreno-cortical adenoma or carcinoma. 3) 2ry: Cushing's disease due to pituitary basophil adenoma which secretes ACTH. 4) Ectopic ACTH syndrome as ACTH is secreted from non-pituitary tumors e.g. lung, kidney, and pancreas carcinoma. 	<ol style="list-style-type: none"> 1) 1ry adrenal insufficiency (Addison's disease) destruction of adrenal gland. E.g. * Autoimmune disease. * 2ries. * Tuberculosis. * Acute hemorrhage in the gland with meningococcal septicemia. This causes combined mineralo-corticoid and glucocorticoid deficiency. 2) 2ry adrenal insufficiency due to decreased ACTH secretions from the pituitary gland. E.g. Exogenous glucocorticoid withdrawal Hypopituitarism. This causes only glucocorticoid deficiency (without mineralocorticoid deficiency).
C/P	<ol style="list-style-type: none"> 1- Hypertension. 2- Hyperglycemia. 3- Musculo-skeletal: * Osteoporosis so care should be taken during positioning and transport. * Muscle weakness so care should be taken with muscle relaxants. * Central obesity (and in between scapulae) (buffalo hump), abdominal striae 4- Hypervolemia and hypokalemic metabolic alkalosis due to mineralo-corticoid action of glucocorticoids. 5- Increased skin pigmentation by ACTH. This differentiates between 1ry and 2ry. 6- Plethoric rounded face (moon face). 7- Poor wound healing and increased infections. 8- Hirsutism and menstrual 	<ol style="list-style-type: none"> a. Cortisol deficiency causes; weakness, fatigue, hypoglycemia, hypotension, weight loss..... ± b. Aldosterone deficiency causes;as above.

	disturbances because ACTH increases androgen also.	
Investigation	1) Dexamethazone suppression test: as dexamethazone will decrease cortisol level in normal patients $< 5 \mu\text{g/dL}$, but not in hyper-adrenocorticism. 2) Increased urinary cortisol excretion $> 150 \mu\text{g/day}$. 3) Loss of diurnal rhythm of s. cortisol (normally $10\text{--}25 \mu\text{g/mL}$ in the morning $2\text{--}10 \mu\text{g/mL}$ in the evening). 4) Increased ACTH indicates pituitary or ectopic causes. 5) CT scan and MRI.	1) ACTH stimulation test: As plasma cortisol is measured before and after ACTH by 1 hour.
Treatment	1) Hypo-physectomy (removal of the pituitary) or adrenalectomy. 2) Steroid cover during adrenalectomy. + Fludro-cortisone $0.1 - 0.3 \text{ mg/day}$ after bilateral adrenalectomy.	1) Steroid cover: Cortisol 100 mg i.v. followed by $10 \text{ mg/hour i.v. infusion.}$ + Fludro-cortisone $0.1 - 0.3 \text{ mg/day.}$

Acute Adrenal Insufficiency (Addisonian Crisis)

Causes: It occurs in steroid dependent patients whose steroid doses are not increased during periods of stress (e.g. infection, trauma or surgery).

C/P: It is a medical emergency.

It has the same, but more severe picture of hypo-adrenocorticism up to circulatory collapse.

Treatment:

a) Supportive:

- Urgent **i.v fluids**, Na^+ replacement with **ABP and CVP** monitoring.
- **Glucose** infusions. - **Vasopressors as dopamine.**
- Correct electrolyte and acid base disturbances
- **Antibiotics** to cover the possibility of infection (which may provoke the crisis).

b) Replacement:

- Hydrocortisone $100 \text{ mg/ 6 hr i.v.}$, dexamethazone 4 mg , or methyl prednisolone 50 mg .
- Fludro-cortisone $0.1 - 0.3 \text{ mg / day}$ in 1ry adrenal insufficiency.

Anesthetic Management:

- 1) From C/P e.g. management of shock.
- 2) Steroid cover \pm fludro-cortisone.

Catecholamine Excess

(Pheochromocytoma or Pheo)

- It is a catecholamine secreting tumor arising from **chromaffin cells**:

- It is **10% extra-adrenal** as para-vertebral sympathetic chain and any area from the base of the skull to the anus where chromaffin cells exist and 90% from the adrenal medulla.
- It is **10% malignant** and 90% benign.
- It is **10% bilateral** and 90% unilateral.
- It is **10% familial (inherited) pheochromocytoma** as autosomal dominant, alone or with MEN syndrome.

N.B.: The word pheochromocytoma is derived from the Greek words for dusky, phaios, and color, chroma. In 1912, Pick noted that these tumors stained a deep rust color when treated with chromium salts.

Pheo secretes 85% norepinephrine and 15% epinephrine in most cases. Normally, the adrenal gland secretes epinephrine 85% and norepinephrine 15% i.e. inverse of the previous ratio. It also secretes dopamine.

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C/P: usually at the 3rd – 5th decade of life.

- There is a triad of headache, palpitation and diaphoresis (i.e. increased sweating).

1) **Paroxysmal attacks** (in 45% of cases) lasting minutes to hours of

- **Hypertension** (may be sustained in 50 % of cases) causing headache and intra-cerebral hemorrhage. ABP may be normal in 5% of cases.

- **Tachycardia and tachyarrhythmias** causing palpitation.

Both occur in **adrenaline predominant** secreting tumors.

2) **Decreased circulatory blood volume** (due to hypertension) causing;

- **Hemo-concentration** (Hct > 45%) and pallor.

- **Orthostatic hypotension.**

Both occur in **noradrenaline predominant** secretion.

3) Increased basal metabolic rate causing **excessive sweating and weight loss.**

4) **Cardiomyopathy, CHF, ischemia, and infarction.**

5) **Hyperglycemia** due to predominant α activity (which decreases insulin release and increases glycogenolysis and gluconeogenesis) over β activity (which increases insulin release).

6) **Renal pathology.**

N.B.; - Unexpected intraoperative hypertension and tachycardia are occasionally the 1st indications of an undiagnosed pheochromocytoma.

- Presence of a normal BP despite increased CA levels in the plasma indicates a decreased number of α receptors (i.e. down regulation) in response to high CAs levels.

Investigations:

	Normal value	Pheochromocytoma
A) <u>Blood:</u> plasma catecholamines.	< 1000 pg/mL	> 2000 pg/mL
B) <u>Urine:</u> (24 hour collection)		
* Total catecholamines	< 125 μ g	> 1200 μ g
* Metanephrines (highest sensitive 99%)	< 1.6 mg	> 2.5 mg
* Vanillyl mandelic acid	< 8 mg	> 10 mg
C) <u>Clonidine suppression test:</u> As confirmation test in equivocal results. 0.3 mg clonidine is given orally.	It suppress norepinephrine secretion in an essential hypertensive patient because clonidine decreases neuronal release of norepinephrine, but does not affect chromaffin cell release.	It does not suppress norepinephrine secretion.

D) Localization of the Tumor:

* CT scan for tumors > 1cm in size.

* MRI.

* Scintigraphy with ¹³¹I labeled metaiodobenzylguanidine (MIBG). It is very accurate.

* Selective adrenal venous catheterization and sampling (for increased CAs concentration).

E) Investigations for Complications:

E.g. * S. glucose for hyperglycemia.

* Echocardiography for heart function.

* Renal function tests.

Anesthetic Management:

Aim: To control the systemic effects of the tumor then to remove it surgically.

Preoperative Management:

Patient Preparation:

1) Block Adrenergic Activities:

a) α Adrenergic Blocking Agents:

- Used to: decrease the peripheral vascular resistance resulting in a decrease in the ABP.

- By: 1- **Phenoxybenzamine:**(Non-selective α_1 and α_2 blocker) (Phental)
 - Either • **Orally: 10 mg/ 8 hrs.** It is increased by 10 mg increments until the diastolic BP is stabilized at 90- 100 mm Hg. Treatment should continue **for 1 week before surgery** to achieve mild orthostatic hypotension.
 - **I.v. infusion: for 3 days** before the surgery with intravascular volume monitoring by CVP and Hct (which drops about 5%) + i.v. colloids.
 - Value: (over competitive antagonists) e.g. prazosin, or labetalol.
 - **It is more efficient** to control the BP even intraoperatively during tumor manipulation due to irreversible alkylation of α receptors.
 - It has a longer duration of action due to irreversible alkylation of α receptors.
- 2- **Phentolamine:** (Regitin)
 - It is used often intraoperatively to control hypertensive episodes.
- 3- **Prazocin** (competitive, selective α_1 antagonist) (Minipress)
 - It is less efficient 2-5 mg/12hr orally.

b) β Adrenergic Blocking Agents:

- It is used to control heart arrhythmias.
- It should always be used **after α blockers and appropriate fluid replacement** because if β blockers are given 1st, unopposed α action occurs causing severe hypertension which causes heart failure due to;
 - Increased afterload on the heart.
 - No β_1 inotropic action.
- By: 1- Propranolol 10 mg /8 hrs orally.
- 2- Labetalol (but, its β blocking action predominates over α blocking which is not desirable).
- 3- Atenolol.

N.B.; Other drugs can be used in patient preparation:

- * MgSO_4 -----→ Those are used with
- * Angiotensin converting enzyme inhibitors---→ phenoxybenzamine to attain
- * Ca^{++} channel blockers-----→ C.V.S. stability
- * α methyl para-tyrosine which inhibits tyrosine hydroxylase decreasing CAs synthesis 40-80%. It is given orally. Gradually increase the dose 0.5 gm/day up to 4 gm/day. It may cause diarrhea, sedation, fatigue, anxiety, depression, and tremors.

2) Correction of Hypovolemia:

- Because α blockers dilate the vascular bed.
- By: 1-2 units blood to increase intravascular volume.

3) Assess Criteria of Adequate Preparation:

- ABP should be < 165/90 mm Hg for 24 hrs before surgery.
- Orthostatic hypotension should be present, but ABP on standing should not be < 80/45 mm Hg.
- ECG: free from ST and T changes for a period of 2 weeks (i.e. no ischemia).
- PVCs should not be > 1/5 min.

Premedication:

- 1) **Sedatives:** to prevent anxiety induced release of catecholamines.
- 2) Anticholinergics: **avoid atropine**. Scopolamine is used instead.
- 3) **α and β blockers:** are **continued** till the day of surgery.
- 4) **Cortisone cover** is used, if bilateral adrenalectomy is planned.

Aim:

- Drugs avoided are:

- Ephedrine • Cyclopropane • Ketamine • Diethyl ether

- ## 2) Drugs that inhibit the parasympathetic nervous system:

- Atropine
- Pancuronium
- Gallamine

- ### 3) Drugs that increase the arrhythmic effect of CAs:

- Halothane.

- 4) Drugs that release histamine:** (Histamine increases CA release from the tumor)

- Atracurium • d- Tubocurarine • Morphine. • Pethidine.

- 5) Other drugs:

- **Suxamethonium:** as abdominal muscle fasciculations increases the intra-abdominal pressure which increases CA release from the tumor.

- Droperidol → see before.....
- Metoclopramide.
- Chlorpromazine.

- **Maneuvers avoided** are;

Fear, stress, pain, shivering, hypoxia and hypercarbia.

Standard +

- ECG (CM₅ configuration).

- **Invasive ABP:** It is done under good sedation and local anesthesia on insertion to avoid sympathetic stimulation by the pain.

- CVP and PAP: They are done under good sedation and local anesthesia on insertion to avoid sympathetic stimulation by the pain.

- Arterial blood gases, s. glucose, and electrolytes.

A) Regional Anesthesia: (for excision of pheochromocytoma).

Disadvantages:

- 1) Although it blocks the sympathetic nervous system, but postsynaptic α receptors are still responding to the direct effects of sudden increase in circulating concentration of CAs.

- 2) Block of sympathetic nervous system exaggerates intraoperative hypotension occurring after ligation of veins draining pheochromocytoma (see later).

- 3) It is only suitable for the supine position.

B) General Anesthesia: (of choice)

Induction:

- Avoid pressor response with intubation.....see before.

- Thiopentone or etomidate are given slowly to avoid hypotension

Maintenance:

O₂/N₂O + Volatile agents + Muscles relaxants and Controlled ventilation.

- Volatile agents: **(No opioid)**

- Isoflurane, enflurane, sevoflurane or desflurane are safe.

- **Halothane is avoided** because it potentiates ventricular arrhythmias.

- Muscle relaxants:

- Vecuronium, rocuronium or pipecuronium are safe.

- **Pancuronium, atracurium or d- tubocurarine** are avoided.

Intraoperative Complications:

- ### 1) Intraoperative Hypertension, Tachycardia and Arrhythmias:

- They occur during tumor manipulation resulting in the release of CAs.

- They are treated by:
 - Na nitroprusside, phentolamine, hydralazine, MgSO₄ or labetalol for hypertension
 - Propranolol or esmolol for tachycardia.
 - Lidocaine for ventricular arrhythmias.

2) Intraoperative Hypotension:

- It occurs **after ligation of the veins** draining the tumor on tumor removal. This decreases CA release with **persistent fatigue of the vasoconstrictor mechanism**, sluggish blood vessel response occurs especially if inadequate intravascular volume is present.
- It is treated by - I.v. volume expansion.
 - Phenylephrine or norepinephrine infusion.

N.B.; Adrenalectomy is done for; • Conn's disease.

- Cushing's syndrome.
- Pheo.

Postoperative Management:

In ICU for continuous invasive monitoring for 12-24 hours postoperatively.

Postoperative Complications:

1) Postoperative Hypertension:

- Due to • Residual pheochromocytoma may be still present.
 - CAs will decrease over many days after removal of the tumor.

2) Postoperative Hypotension.

3) Postoperative Hypoglycemia:

- Because • Suppression of Beta cells of the pancreas disappears after tumor removal which increases the insulin levels.
 - Gluconeogenesis and glycogenolysis are no longer present.
- So, give glucose containing solutions.
- 4) Patient may be very somnolent in the 1st 48 hours
 - Due to • Sudden removal of activating CAs.
 - Hypoglycemia.

Carcinoid Tumors and Syndrome

Causes:

- Carcinoid tumors are **entero-chromaffin tumors** which secrete about 20 different vasoactive substances e.g. serotonin, kallikrin, histamine, PGs, substance P.....

- Sites:

- Most tumors arise in **the GIT**. It leads to secretion of vaso-active substances which reach the portal circulations then to the liver. Then they are metabolized so, systemic effects (and C/P) do not appear i.e. no carcinoid syndrome except if vaso-active substances amount exceeds the liver ability to inactivate them.
- Other tumors arise in **pulmonary, ovarian or hepatic secondaries**. They bypasses the portal circulation so, systemic effects (and C/P) appear i.e. carcinoid syndrome occurs. 4% only of carcinoid tumors cause carcinoid syndrome.
- 4% are malignant causing hepatic secondaries which cause the carcinoid syndrome.

Q: What are the tumors arising from chromaffin cells?

A: They are pheochromocytoma and carcinoid tumors.

C/P of Carcinoid Syndrome:

1) Serotonin (5-Hydroxy-Tryptamine):

- VC causes coronary artery spasm and hypertension.

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- **Increased intestinal tone** causes - Chronic intermittent abdominal **pain**.
 - Profuse **diarrhea** results in water and electrolyte imbalance.
- **Hyperglycemia** as serotonin stimulates glycogenolysis and gluconeogenesis.
- **Hypoproteinemia and pellagra** due to tryptophan deficiency used in serotonin synthesis.
- **Right sided heart failure** due to vascular and myocardial plaque formation which causes pulmonary and tricuspid stenosis. (Lung metabolism of serotonin prevents affection of the left side of the heart but left side heart failure can occur by bronchial carcinoid tumor).
- 2) **Kallikrin:** (it acts on plasma kininogen causing bradykinin).
 - **VD** causes hypotension and flushing of the face, neck, trunk and upper limbs. (i.e. **Carcinoid flush = Red Man Syndrome**. It is precipitated by alcohol, blue cheese, chocolate, red wine and exercise).
 - **Bronchospasm**.
- 3) **Histamine:**
 - **VD** causes
 - **Bronchospasm**.
 - **Dysrhythmias** e.g. APCs, and SVT.
- 4) **Prostaglandins and substance P:**
 - **VD** causes
 - Increased intestinal tone causes diarrhea.

Investigations:

5-Hydroxyl Indole Acetic Acid (5-HIAA) in urine (a serotonin metabolite) > 27 mg/ day is diagnostic.

Anesthetic Management:**Preoperative Management:****1) Patient Preparation:** By;**1) Somatostatin** ($t_{1/2}$ is 1-3 min)

Or **somatostatin analogue (Octreotide)**. Its $t_{1/2}$ is 45 min. Its dose is 150 µg sc/8 hrs.

- Value: They are growth hormone release inhibitory hormone, but they also inhibit the release of vaso-active peptides. So, they protect against carcinoid crisis.

2) Anti-serotonin drugs:

E.g. • Serotonin receptor antagonists as methysergide, ketanserin or cyproheptadine.

• Inhibitors to serotonin synthesis as α methyl dopa.

3) Anti-kallikrin drugs e.g. corticosteroids or aprotonin.**4) Anti-histaminic drugs** e.g. H_1 and H_2 blockers.**2) Symptomatic treatment:**

• Salbutamol and /or aminophylline to treat bronchospasm.

• Loperamide to treat diarrhea.

• Digitalis and diuretics to treat right sided heart failure.

3) Assess C.V.S. function for heart failure.

Patients may need preoperative valve replacement.

Intraoperative Management:**Monitoring:**

Standard +

• Invasive ABP.

• CVP and PCWP.

Choice of Anesthesia:**A) Regional Anesthesia:**

- It is **not preferred** as this may cause hypotension which precipitates carcinoid crisis.

- It is only done provided that no hypotension, no perioperative stress and fear so, it needs also **good sedation**.

B) General Anesthesia:

Induction:

- By **fentanyl and muscle relaxants** e.g. vecuronium for intubation.
- **Avoid i.v. agents** e.g. propofol, or thiopentone as they cause hypotension.

Maintenance:

- O₂/ N₂O + Fentanyl + Muscle relaxant with controlled ventilation.
- **Inhalational agents are avoided** as they cause hypotension.
- Opioids as **morphine are avoided** as they cause histamine release.
- Muscle relaxants as **atracurium, or tubocurarine are avoided** as they cause histamine release.
- IPPV: It is better by **flow generator type ventilators** which can deliver inspired gas at high pressures if bronchospasm occurs.

Intraoperative Complications:

Carcinoid crisis There is **severe hypotension, hypertension, or/& bronchospasm**. So, **avoid factors** that precipitate carcinoid crisis i.e. factors release vaso-active peptides e.g. 1) **Hypotension:** So, avoid - Regional anesthesia.

- I.v. and inhalational agents.
- Deep anesthesia.
- Hypovolemia (increased by diarrhea).

It is treated by volume expansion.

2) Histamine release:

So, avoid morphine, atracurium, and tubocurarine.

3) Sympathetic stimulation: It increases CAs which stimulate kallikrins So, avoid ketamine.

4) Surgical manipulation:

- So, • Octreotide 50 µg i.v. + 50 µg s.c is given before tumor manipulation.
- Other anti-mediators can be used as above.
- Avoid the use of ordinary inotropes or vasopressors if CV collapse occurs as they may precipitate mediator release so, if a vasopressor is needed **methoxamine** is the **recommended** one.

Postoperative Management:

In ICU, postoperative controlled ventilation may be needed.

Pituitary Gland

- It is located in the sella turcica at the base of the brain.

- It is formed from:

- Anterior Pituitary:** under control of the hypothalamus by **vascular** connections as hypothalamic hormones travel by the hypophyseal portal veins to reach the anterior pituitary (**Adeno-hypophysis**).
- Posterior Pituitary:** is composed of terminal endings of neurons. They originate in the hypothalamus (supraoptic and para-ventricular nuclei) (median eminence) as hormones are synthesized in these nuclei and then transported along the hypothalamic neuronal axons (pituitary stalk) for storage in the posterior pituitary (**Neuro-hypophysis**).

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Hypothalamic Hormones	Anterior Pituitary Hormones
1) Growth hormone- releasing hormone.	- Growth hormone.
2) Growth hormone release-inhibiting hormone.	- Growth hormone.
3) Prolactin release inhibitory factor (dopamine)	- Prolactin, FSH, and LH.
4) Gonadotropin releasing hormone.	- Follicle stimulating hormone (FSH) and luteinizing hormone (LH).
5) Corticotropin releasing hormone.	- Adreno-corticotrophic hormone (ACTH).
6) Thyrotropin releasing hormone.	- Thyroid stimulating hormone (TSH).

Hypothalamic Synthesis Site	Posterior Pituitary Hormone.
1) Supra-optic nuclei.	- Antidiuretic hormone.
2) Para-ventricular nuclei.	- Oxytocin.

C/P of Pituitary Tumors:

- 1) **Increased ICT:** headache, vomiting, and papilloedema.
- 2) **Compression on the surrounding structures:**
 - 1- Optic chiasma (roof of sella turcica) which causes visual field defects (bi-temporal hemianopia).
 - 2- Hypothalamus (above chiasma) which causes temperature and circulatory changes.
 - 3- Roof of the nose (floor of sella turcica) which causes rhinorrhea.
- 3) **Endocrine manifestations:**
 - 1- Due to functioning tumors:
 - Increased growth hormone which causes acromegaly in adults, or gigantism in pre-pubertal age
 - Increased ACTH which causes Cushing's disease.
 - 2- Due to compression on the gland itself:
 - Decreased secretions of all hormones which causes pan-hypopituitarism (common).
 - Decreased secretions of a single hormone which cause mono-tropic deficiency (very rare) e.g. diabetes insipidus.

Investigations:

- 1) CT scan shows enlarged sella turcica.
- 2) MRI shows enlarged sella turcica.

Surgical Approaches are either;**a) Bi-Frontal Craniotomy:**

- For tumors > 20 mm in diameter with significant suprasellar extension.
- Anesthetic management and problems: as in craniotomy "see anesthesia for neurosurgery".

b) Trans-Sphenoidal Route:

- For tumors < 10 mm in diameter.
- By using the microscope, via an incision in the gingival mucosa under the upper lip.

Anesthetic Problems:

- 1) **Increased risk of infection** due to working through the nose.
So, prophylactic antibiotics are given.
- 2) **Increased blood loss** through the nose.
So, mucosal injections of epinephrine containing solution are needed.

3) **Accumulation of blood and tissue debris in the pharynx and stomach.**
So, a pharyngeal pack and good suctioning are needed.

4) **Injury to the surrounding structures:**

- a) Structures lateral to sella turcica:
 - Injury to the **cavernous sinus**.
 - Injury to the **internal carotid artery**.
 - Injury to the **cranial nerves III, IV, V, and VI**.
- b) Structures superior to sella turcica:
 - Injury to the **optic nerve** so, visual evoked potential monitoring is needed.

5) **Venous air embolism:**

Due to slightly head up position.

6) **Associated pituitary dysfunction:**as above.

Acromegaly

There is an increase in the growth hormone secretion due to **acidophil adenoma** (eosinophil cell tumor) after puberty.

In pre-puberty, before fusion of the **epiphysis**, gigantism occurs.

Anesthetic Problems:

- 1) **Cardiomegaly, hypertension, congestive heart failure, premature coronary disease, and cardiomyopathy:** They should be assessed and managed.
- 2) **Hyperglycemia.**
- 3) **Upper airway obstruction due to:**
 - Enlarged mandible, tongue, and **epiglottis**.
 - Thickened pharyngeal mucosa, **laryngeal** narrowing, and vocal cord enlargement.

This causes **difficult airway management and intubation**.

So, * It needs preoperative assessment and indirect laryngoscopy.

 - * Preparation for difficult intubation e.g. larger laryngoscope blade, smaller tube size and even awake intubation.
 - * Avoid nasal intubation due to **enlargement** of nasal turbinates.
 - * Postoperative care for airway **obstruction**.
- 4) **Peripheral neuropathy** e.g. **carpal tunnel syndrome**.
- 5) **Osteoarthritis and osteoporosis** so, care is taken during positioning.
- 6) **Skeletal muscle weakness:** so, decrease the non-depolarizing muscle relaxant doses and use a nerve stimulator.
- 7) **Skeletal overgrowth:** So, there is **difficult** regional anesthetic techniques.
- 8) **Avoid intra-arterial cannulation in the radial artery** because there is usually impaired ulnar artery circulation resulting in loss of blood supply of the hand causing hand ischemia.
- 9) **Steroid and thyroxin cover** due to impaired adrenal and thyroid function association.

Hypopituitarism **(Simmond's Disease)**

Causes:

- 1) **Infarction** after postpartum hemorrhage.
- 2) **Infection.**

ANESTHESIA WITH/FOR ENDOCRINE DISEASES

- 3) Hemorrhage in the pituitary gland (pituitary apoplexy).
- 4) Tumors of surrounding tissues e.g. **cranio-pharyngioma**.
- 5) Tumors of the gland itself e.g. **chromophobe adenoma**.
- 6) Skull fracture.
- 7) A sequel to a pituitary surgery.

Anesthetic Problems:

On compression of the gland, the following may occur;

- 1) **Gonado-trophin deficiency** (1st to occur):

This causes impotence in ♂ and amenorrhea in ♀.

- 2) **ACTH deficiency** resulting in 2ry adrenal insufficiency (2nd to occur within 2 weeks):

This causes;

- * Severe pallor (in contrast to pigmentation of 1ry adrenal insufficiency as increased ACTH causes increased pigmentation).
- * Fluid and electrolyte imbalance (It is not marked as in 1ry adrenal insufficiency due to intact aldosterone secretion).

- 3) **TSH deficiency** resulting in 2ry hypothyroidism (3rd to occur within one month).

- 4) **Steroid and thyroxin cover** is needed.

Diabetes Insipidus

C/P: - Polyuria of poorly concentrated urine.

- Polydipsia.
- Increased plasma osmolality > urine osmolality.

a) Central Diabetes Insipidus:

- **Cause:** Disease or damage affecting the **hypothalamic-posterior pituitary axis** resulting in a decrease in ADH secretions (the same causes of hypopituitarism as above.....).

- **Investigations:** Increase in urine osmolality after giving exogenous ADH is used as a confirmatory test.

- **Treatment:**

- Fluid replacement.
- ADH replacement by;
 - 1) **Aqueous vasopressin:** 5 units s.c/ 4 hours. It is of choice in **acute** cases.
 - 2) **Vasopressin in oil:** 0.3 mL i.m./ day. It is long acting and may cause water intoxication.
 - 3) **Desmopressin (DDAVP):** a synthetic analogue of ADH:
Intranasal 5-10 µg/ 6- 12 hours. It is long acting 12- 24 hrs. It can be used in the outpatients and perioperatively.

b) Nephrogenic Diabetes Insipidus:

- **Cause:** ADH secretion is normal, but the **kidneys fail to respond to ADH**. This causes impaired kidney concentrating ability due to;

- 1) **Congenital.**

- 2) **Acquired:** * Chronic renal diseases.

* Sickle cell disease.

* Electrolyte disturbances e.g. hypokalemia, and hypercalcemia...

* Hyper-proteinemia.

- 3) **Drugs:** * Amphotericin B.

* Demeclocycline.

* Lithium.

* Methoxyflurane.

* Mannitol.

* Colchicines.

* Vincristin.

- **Investigations:** No increase in urine osmolality after giving exogenous ADH is used as a confirmatory test.

- **Treatment:**

1- Treatment of the cause.

2- Fluid replacement.

3- Some trials of;

▪ **Chlorpropamide (oral hypoglycemics):** It potentiates ADH action.

▪ **Thiazide diuretics:** They cause volume depletion which produces paradoxical decrease in water delivery to renal tubules. This leads to decreased UOP.

▪ Na^+ and protein restriction is needed to decrease UOP.

Q: What is the diuretic indication for patients with polyuria?

Multiple Endocrine Neoplasm (MEN)

It is a group of syndromes characterized by tumor formations in several endocrine organs. It is usually hereditary.

Types:

1) **MEN Type I:** It consists of 3 Ps.

- Pancreatic tumors (Gastrinoma or insulinoma).

- Pituitary tumors (chromophobes).

- Parathyroid tumors.

2) **MEN Type II:**

- Medullary thyroid carcinoma: It secretes calcitonin which decreases Ca^{++} , and causes diarrhea.

- Pheochromocytoma.

- Then **type IIa (Sipple's syndrome):** parathyroid adenoma.

or **type IIb or type III:** Multiple mucosal neuroma + Marfanoid appearance.

N.B.; If multiple surgeries are planned for tumor excision, pheochromocytoma resection should be scheduled first.

CHAPTER 20

ANESTHESIA FOR VASCULAR SURGERY

Anesthesia for Carotid Endarterectomy

It is the removal of atheromatous plaques from the vessel lumen. If the remaining intima is too thin, the vessel is closed with a vein or a synthetic (Dacron) patch.

Pathology:

Atherosclerotic Carotid Artery Disease

- It is a part of atherosclerosis which affects many arteries. It results in a decrease in cerebral blood flow up to complete obstruction of the carotid artery due to;
 - **Embolism:** It occurs from any detached atherosclerotic plaque.
 - **Hemorrhage:** due to its rupture.
 - **Thromboembolic:** as thrombosis occurs on the plaque which narrows the lumen to a great degree.

- C/P:

1) Cerebral Stroke:

- It is a **neurologic deficit** that lasts **more than 24 hours**. It usually causes hemiplegia due to focal cerebral infarction.

2) Transient Ischemic Attacks (TIAs):

- They are **neurologic deficits** that **resolve within 24 hours**. They usually cause hemiparesis due to focal cerebral ischemia.

3) Chronic Cerebral Ischemia.

4) Asymptomatic Carotid Bruit:

N.B.; Perioperative mortality varies with the symptoms:

- Frank stroke 6%
- TIAs less
- Chronic cerebral ischemia..... less
- Asymptomatic..... 0%

Anesthetic Management:

Preoperative Management: by history, examination, and investigations.

1) Preoperative Assessment for the C/P of Carotid Artery Disease:

- Assess the **perioperative mortality rate** as above.....
- Assess the patient's **airway and ventilation** as the range of the patient's tolerated neck motion without evidence of cerebral ischemia should be determined.

2) Preoperative Assessment of Other Manifestations of Generalized

Atherosclerosis: E.g. hypertension, ischemic hearts, renal diseases.....

3) Preoperative Assessment of Other Coexisting Diseases:

Because the patient is usually **elderly and a heavy smoker** so, the patient may be with;

- Pulmonary diseases e.g. COPD.
- Diabetes mellitus.

- Hypertension, ischemic heart and CHF. It is still a controversy if the patient is with both carotid and coronary diseases as the risk is increased in one of them if the other is done first. Some authors advocate the management of coronary disease first but most other authors advocate the management of carotid disease first.

- Renal diseases.

4) Preoperative Drug Therapy:

- All antihypertensive and antianginal treatment should be continued till the day of surgery (except diuretics) to avoid rebound phenomenon.
- Aspirin may increase the bleeding time.

5) Preoperative Investigations:

Standard +

- Cerebral angiography.
- Coagulation profile.
- Trans-cranial Doppler.
- For associated diseases e.g. pulmonary function tests, s. glucose, echocardiography, kidney function tests etc.

6) Premedications:

1) Sedatives :

- To avoid the increase in HR and BP as both aggravate myocardial ischemia and neurologic deficits.

- By: • Reassurance.

- Diazepam 5 mg orally 1 hour preoperatively.

2) Anticholinergics: e.g. atropine:

- Are avoided especially in ischemic heart disease due to tachycardia.

Intraoperative Management:

There is clamping of common, internal and external carotid arteries during removal of atheromatous plaques and during arterial reconstruction.

So, the major anesthetic problems are:

- Cerebral ischemia: so, avoid cerebral hypoperfusion.
- Myocardial ischemia: so, make balance between O₂ supply and demand.

Monitoring:

Standard +

- ECG: CM₅ (lead II and V₅) or automatic ST segment analysis are used to detect ischemia.
- UOP.
- Temperature: by esophageal or tympanic membrane probe.
- CVS monitoring as PAP, CVP, CO measurement, and trans-esophageal echocardiography.
- Invasive ABP.
- AB gases.

- **Monitoring of Cerebral Perfusion** (it is done at an early stage before clamping).

a) If Local (Regional) Anesthesia is used:

- Repeated neurologic assessment is done in **awake patients** after initial clamping for the level of consciousness, speech and contralateral hand grip.
- It is the **most reliable and sensitive method**. It is the **gold standard** for neurologic monitoring.

b) If General Anesthesia is used:

None of the following methods are as reliable as repeated neurologic assessment in awake patients. These methods include.

1) Jugular-Venous O₂ Saturation (SjvO₂):

$$- \text{CBF} = \frac{\text{Cerebral Metabolic rate for O}_2}{\text{SaO}_2 - \text{SjvO}_2}$$

- As long as arterial O₂ content is constant; a decrease in the jugular venous O₂ saturation indicates either decreased CBF or increased cerebral MRO₂ without a simultaneous increase in CBF.

- It is **unreliable** because it is an accurate monitor of global rather than regional CBF.

2) Internal Carotid Distal Stump Pressure (Occlusion Pressure):

- It measures the pressure in the portion of the internal carotid artery cephalad to the carotid cross-clamp.

- It reflects the pressure transmitted through collateral vessels (figure 20-1).

- It is **unreliable** because it does not correlate consistently with changes in EEG, rCBF or changes in the neurologic status of the awake patient.

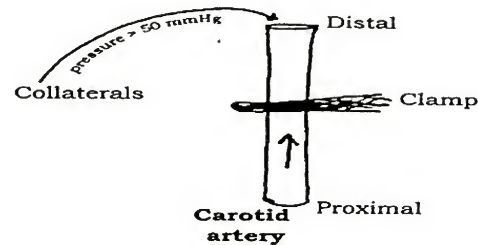


Figure 20-1; Stump pressure

3) Measurement of CBF:

By trans-cranial Doppler....."see CNS monitoring".

4) EEG (Unprocessed or Processed):

- It is **unreliable** because it is **not sensitive or specific** in detection of cerebral ischemia.

5) Somato-Sensory Evoked Potentials (SSEPs):

- It is **unreliable** because it is **not sensitive or specific** in detection of cerebral ischemia.

6) Observation of Retrograde Flow From Opened Carotid Artery.**7) Trans-Conjunctival O₂ Tension:**

- It is **unreliable** because it is **not sensitive or specific** in detection of cerebral ischemia.

8) Cerebral Oximetry (Near-Infrared Spectroscopy).**Choice of Anesthesia:****A) Regional Anesthesia: By;**

- Cervical plexus block (deep and superficial).
- Cervical epidural anesthesia.
- Local infiltration.

Or a combination of them.

- Advantages:

- 1- It allows repeated neurologic assessment in **awake patient**.
- 2- It allows **greater ABP stability** so, decreases the incidence of myocardial infarction perioperatively.

- Disadvantages: (opposite to the advantages of GA)

B) General Anesthesia:

- Advantages:

- 1- It allows the patient to be quiet especially for **long time surgery**.
- 2- It allows **early control of respiration**.
- 3- It allows **brain protective measures** to be taken.
- 4- **Avoid excessive neck palpation** (which could occur during performing local anesthesia) because regional anesthesia can lead to dislodgement and subsequent embolization of a portion of plaque.

- Disadvantages: (opposite to the advantages of LA)

Induction:**Smooth induction**

- Preoxygenation with 100% O₂ for 5 min is essential.
- Thiopentone or etomidate can be used.
- Nondepolarizing **muscle relaxants** as vecuronium or cisatracurium **without CVS effect** are preferred.
- **Avoid suxamethonium in hemiparetic patients** for the possibility of hyperkalemia.
- Avoid the pressor response to intubation by

Maintenance:

O₂/N₂O (5:5) + Volatile agents + Opioids + Muscle relaxant + Controlled ventilation.

- O₂/N₂O (50%) is used. Avoid 100% O₂ as it causes cerebral vasoconstriction.

N₂O is stopped before opening the vessels to avoid air embolism.

- Volatile agents: **Isoflurane, sevoflurane, and desflurane are of choice.**

Intraoperative Problems:**1) Brain Protection Measures:** (during the period of carotid clamping)**A) Measures to Increase CBF:**

1- **Elevate ABP to high normal ranges** or slightly higher 15 – 25% above upper limits (up to 170 mm Hg).

- So, avoid hypotension by:

- Light anesthesia and judicious amounts of i.v. fluids.
- Phenylephrine i.v. infusion or 25 µg i.v. increments.
- Avoid extreme increases in ABP by:
- Nitroglycerine infusion: It is of choice because it vasodilates coronary vessels too.
- Na nitroprusside infusion.

2- Ca⁺⁺ channel blockers: Nimodipine:

It has a vasodilator effect especially on cerebral vessels so, it protects against focal ischemia.

3- Decrease ICP by dehydrating measures.....

4- Hemodilution is advised to maintain Hct at 30%.

B) Measures to Decrease CMRO₂:

1- Anesthesia by **isoflurane or sevoflurane** as both **decrease the critical CBF** (i.e. CBF at which ischemia occurs) as compared to halothane and enflurane.

2- **Hypothermia** up to core temperature of 30°C (not used nowadays), but hyperthermia should be avoided.

3- Anticonvulsants.**4- Barbiturates as thiopentone.**

- Five mg/Kg/hr or 50 mg increments (total dose 500 – 1500 mg) to avoid hypotension.
- EEG monitor should be used to achieve and maintain burst suppression pattern. When EEG becomes isoelectric it indicates non-functioning neurons. Further doses of thiopentone will not provide additional cerebral protective effects.
- Value of thiopentone: in protection of **focal (and not global) ischemia**.
- Mechanism of action as brain protection:....."see before in Aesthesia for neurosurgery".

C) Others Measures:

1- **Control PaCO₂** as above.

2- Bypass (temporary) shunt:

- Between common carotid artery and distal internal carotid artery.
- Disadvantages: • It does **not guarantee** an adequate CBF.
- It makes the surgical technique **more difficult**.

- It may cause **plaque embolization, thrombo-embolism, air embolism**, or intimal dissection.

3- **Hyperbaric O₂**: It increases cerebral O₂ delivery and causes VC in normal brain tissues.

4- **Heparinization**: 5000 – 10 000 IU heparin i.v. before carotid occlusion then reversal by protamine 50 – 75 mg before skin closure.

5- **S (+) Ketamine**: It is neuro-protective as it is a more potent NMDA antagonist than the racemic mixture of ketamine which is commercially available.

6- **Dexmedetomidine**: It is neuro-protective although it decreases CBF.

2) Intraoperative Hypo – or Hypertension:

It is treated as above.....

3) Intraoperative Arrhythmias:

a) Reflex Bradycardia:

- It occurs due to **manipulation of the carotid sinus by the surgeon.**

- Treatment:

- Prophylactic infiltration of the carotid sinus by lignocaine (but this itself may cause bradycardia).
- I.v. atropine.

b) Reflex Tachycardia:

- Treatment: β blockers.

4) Reperfusion Injury (Hyper-reperfusion Syndrome):

After repair of carotid stenosis, blood flow to the areas distal to the stenosed carotid artery is resumed and perfusion pressure is markedly increased. Because the auto-regulatory mechanisms are lost, CBF is increased in response to the increase in perfusion pressure.

5) Intraoperative Fluid Therapy:

- Amount: It is better to be limited to 10 – 15 mL/Kg/hour.

+ Blood loss.

- Types: • NS and ringer solution.

- Colloid or blood for blood loss.

- **Avoid dextrose containing solutions** because hyperglycemia worsens the neurologic outcome after cerebral ischemia.

Recovery:

Smooth rapid recovery is needed to allow **immediate neurologic assessment**, but it may cause hypertension or tachycardia which requires treatment.

Postoperative Management:

Postoperative Complications:

1) Delayed Recovery From General Anesthesia (or Postoperative Neurologic Dysfunction):

1- **Exclude causes** as hypoglycemia, hyperglycemia, hypothermia, hypoxia, hypercapnia, and anesthetic overdosage.

2- **Patency of the carotid artery on which the surgery was performed should be evaluated** in the operating room by **doppler studies**.

- If there is no blood flow in the carotid artery, the incision should be immediately reexplored.

- If there is normal blood flow in the carotid artery, so, intraoperative cerebral infarction should be considered.

2) Appearance of New or Increased Preexisting Neurologic Deficits:

- Cranial nerve dysfunction VII, IX, X, XII (IX, X need intubation)the same as above.

- Recurrent laryngeal nerve injury causing hoarseness of voice, impaired cough and respiratory insufficiency.

3) Hemodynamic Instability:

a) Hypertension: (more common):

- Causes: • Pain, hypoxia, hypercarbia, or full bladder.
 - **Blunting of carotid baroreceptor mechanisms 2ry to carotid sinus dysfunction induced by surgical trauma or LAs.**

b) Hypotension:

- Causes: • Hypovolemia and residual effect of anesthetics.
 - Myocardial ischemia and cardiac arrhythmias.
 - Residual effect of antihypertensive drugs used intraoperatively.
 - **Increased sensitivity of the carotid sinus due to exposure of the carotid baroreceptor mechanism to higher pressures following removal of the plaque and repair of the stenosis.**

4) Respiratory Insufficiency: It is a life threatening condition.

- Cause: • Vocal cord paralysis due to traction on **the recurrent laryngeal nerve** requiring immediate re-intubation.
 - **Neck hematoma** which needs immediate evacuation.
 - **Neck edema** which needs awake intubation (opening of the wound is not effective).
 - **Phrenic nerve paralysis** due to cervical plexus block. It only causes respiratory insufficiency if there was severe pulmonary disease or diaphragmatic dysfunction on the other side.

5) Tension Pneumothorax:

- It causes respiratory distress, absent breath sound, and hemodynamic instability.
- Cause: Air dissecting through the wound and mediastinum to the pleura.

Anesthesia for Aortic Surgery

Indications of Aortic Surgery:

- Aortic aneurysm.
- Aortic dissection.
- Aortic occlusive disease.
- Aortic trauma
- Coarctation of the aorta.

Coarctation of the Aorta:

It is a congenital disease either:

I) Preductal (infantile) type	II) Postductal (adult) type
The narrowing segment is present proximal to the ductus arteriosus.	The narrowing segment is present distal to the ductus arteriosus.
C/P: It appears in infancy .	C/P: It appears at adulthood .
1- The upper half of the body is well perfused (not cyanotic) due to its good perfusion mainly from the aorta.	1- The severity of C/P depends on the severity of the narrowing and the extent of collateral circulation.
2- The lower half of the body is poorly perfused (cyanotic) because it is perfused from pulmonary artery by un-oxygenated blood.	2- Hypertension and strong pulse in the upper limb while hypotension and weak pulse in the lower limb.
3- LVF usually occurs in the 1 st week of life.	3- LVF .
4- Associated congenital anomalies as <ul style="list-style-type: none"> • PDA in 2/3 of cases. • VSD in 1/3 of cases. • Bicuspid aortic valve in 1/4 of cases 	4- Systolic murmur over the stenotic area in left paravertebral area. <ul style="list-style-type: none"> • Continuous murmur over the collaterals. • Cerebral hemorrhage, rupture of aorta, and bicuspid aortic valve can occurs.
Treatment: Surgical repair:	Treatment: Surgical repair.

Parts of the Aorta:

Part (I) Ascending aorta: between the aortic valve and innominate artery.

Part (II) Arch of aorta: between the innominate artery and left subclavian artery.

Part (III) Descending thoracic aorta: between the left subclavian artery and the diaphragm.

Part (IV) Abdominal aorta: below the diaphragm (figure 20-2).

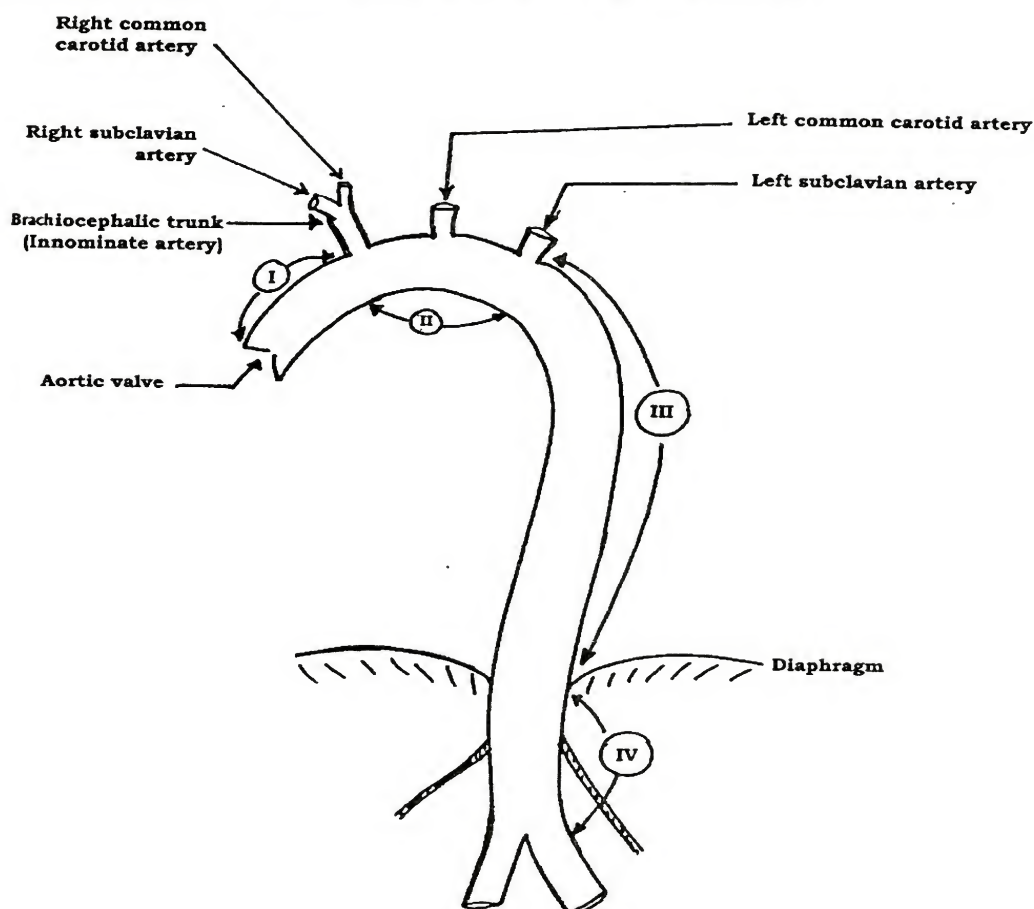


Figure 20-2; Parts of the aorta

- During surgeries in the **ascending aorta**, care is taken for **coronaries and aortic valve**.
- During surgeries in the **arch of the aorta**, care is taken for **cerebral** circulation.
- During surgeries in the **thoracic aorta**, care is taken for **spinal and renal** circulation.
- During surgeries in the **abdominal aorta**, care is taken for **renal and spinal** circulation.

Anesthetic Management:**A) Surgery on the Ascending Aorta:****- Anesthetic Problems:**

1. It needs **cardio-pulmonary bypass** (as cardiac surgery).
2. **Aortic regurgitation** may occur needing aortic valve replacement.
3. Affection of **coronary vessels** may occur so; it may need coronary re-implantation.
4. There are long aortic cross-clamp times.
5. There is a large intraoperative **blood loss** (aprotinin may be used)

6. **The left radial artery** is used to monitor invasive BP because clamping of the innominate artery may be done during the procedure (the femoral and dorsalis pedis are suitable alternatives).

B) Surgery on the Arch of Aorta:

- Anesthetic Problems:

- 1) It needs **cardio-pulmonary bypass with deep hypothermic circulatory arrest**.
- 2) **Optimum brain protection** is needed by;
 - Deep hypothermia 15°C.
 - Thiopentone infusion to obtain a flat EEG.
 - Methyl prednisone.
 - Mannitol.
 - Phenytoin.
- 3) Large intraoperative **blood loss** may occur due to long re-warming periods.

C) Surgery on Thoracic and Abdominal Aorta:

Anesthetic Management:

Preoperative Management:

- The same as carotid endarterectomy....."see before".
- Before an elective surgery for the aortic aneurysm, **carotid endarterectomy may be indicated** for patients with transient ischemic attacks or minor strokes with good neurologic functions.
- Asymptomatic carotid bruits are not an indication for delaying surgery as there is no evidence that these patients are at increased risk for strokes.
- Two large i.v. cannulas (14 gauge) are inserted.

Intraoperative Management:

Monitoring:

As carotid endarterectomy (except cerebral function monitoring)

+ • Arterial cannula:

- In abdominal aortic surgery: Both radial arteries can be used.
- In **thoracic aortic surgery: Only right radial artery + femoral or dorsalis pedis.**
Avoid the left radial artery because the left subclavian artery may be clamped during the surgery. Both right radial and femoral or dorsalis pedis are used to monitor ABP above and below the aortic clamp.
- **Somato-sensory evoked potentials (SSEPs)** for spinal cord function are needed in thoracic aortic surgery.

Choice of Anesthesia:

A) Combined general anesthesia + lumbar epidural block.

Or only lumbar epidural block (In abdominal aorta only).

- Advantages:
 - It decrease the anesthetic requirements of GA.
 - It decreases the release of stress hormones to surgery.
 - It provides postoperative epidural analgesia.
 - It decreases the hyper-coagulability and thrombotic events.
- Disadvantages:
 - Epidural catheters should be inserted before patient's heparinization otherwise epidural hematoma may occur which causes diagnostic confusion between epidural hematoma and post-ischemic spinal cord injury.

ANESTHESIA FOR VASCULAR SURGERY**B) General Anesthesia** (In thoracic and abdominal aortic surgery)**Induction:**

Smooth inductionas carotid endarterectomy.

- + • In thoracic aortic aneurysm, the patient lies in the lateral position.

One lung anesthesia by double lumen tube (Robert Shaw tube) or Univent bronchial blocker is indicated.

- Value: 1) It enhances surgical exposure by collapsing the nondependent left lung and protects the lung from the trauma of surgical retraction.
- 2) Isolation of the right lung from spillage of blood during initial surgical dissection and manipulation.
- Technique and assessment of proper positioning of double lumen tube "see thoracic anesthesia".

Maintenance:

- a) If good ventricular function is present, **balanced anesthesia** is needed.

$O_2 \pm N_2O$ + low concentration volatile agents + moderate dose fentanyl + muscle relaxants + IPPV.

- N_2O is avoided during one lung anesthesia as high O_2 is needed to avoid hypoxia.

- Low concentration of volatile agents:

- They inhibit hypoxic pulmonary VC which may cause hypoxia.
- Isoflurane > 1% may cause coronary steal which may cause heart ischemia in patients with coronary artery disease.

- b) If bad ventricular function is present, **opioid based anesthesia** is needed.

- It has minimal cardiac depression and allows the use of a high FiO_2 .

Intraoperative Problems:**1) Cross Clamping of the Aorta:**

- Effects:

- a- Proximal to the clamp, **hypertension** occurs which causes;

- Increased afterload: It increases the cardiac work which aggravates **heart ischemia, arrhythmias, and LVF** (i.e. There are increase in CVP and PCWP and decrease in cardiac index).
- Increased ICP: It causes cerebral hemorrhage.

- b- Distal to the clamp, **hypotension** occurs which causes;

- **Renal ischemia:** It leads to acute renal failure (acute renal tubular necrosis).
- **Spinal cord ischemia:** It leads to paraplegia.

- Management:

- In both thoracic and abdominal aortic surgery.

1- Vasodilators: Nitroglycerine or Na^+ nitroprusside.

- They are used cautiously because they decrease renal and spinal cord blood flow in a dose related fashion.

2- Inhalational Anesthetics:

- They decrease ABP by cardiac depression and the vasodilating effect.

- In thoracic aortic surgery only:

3- Partial Cardio-Pulmonary Bypass:

- Either: • Partial left heart bypass: The blood is drained from the left atrium to a reservoir and then pushed by a roller pump to the femoral artery.

- Femoral veno-arterial bypass: The blood is drained from the femoral vein to a pump oxygenator and then pushed by a roller pump to the femoral artery.

- **Systemic heparinization is needed** which increases the blood loss so, some authors avoid the partial CP bypass.

4- Shunting Technique:

- A shunt is done from the left ventricular apex or proximal aorta to the distal aorta or femoral artery.
- Systemic heparinization is not needed because a heparin bonded or coated tubes are used.

5- Selective Perfusion:

- It allows arterial flow via the mesenteric and splanchnic circulation. Small catheters are used to cannulate the mesenteric, celiac, and renal arteries.

6- Cardio-Pulmonary Bypass with Deep Hypothermic Circulatory Arrest:

- Advantages:
- It can protect the spinal cord and kidneys.
 - It provides a bloodless field.

- Disadvantages:
- There is increased post-bypass bleeding and transfusion need.
 - There is increased duration of surgery.
 - The usual risks of full CPB.

2) Spinal Cord Protection:**Causes of Spinal Cord Injury:**

- Cross clamping decreases spinal cord perfusion which leads to ischemic injury.

Monitoring:

- By SSEPs as ischemia of the spinal cord increases the latency \pm decreases the amplitude.
- **Postoperative paraplegia** has been reported despite normal intraoperative SSEPs. This suggests that SSEPs monitoring may fail to reflect spinal cord dysfunction on 2 conditions:
 - If the insult does not involve the dorsal column (sensory).
 - If the insult does involve the dorsal column, but is not of sufficient magnitude to affect the SSEPs.

N.B.; Blood supply of the spinal cord (figure 20-3):

The spinal cord is supplied by a single anterior spinal artery (it supplies 75% of spinal cord) and 2 posterior longitudinal arteries (they supply 25% of spinal cord). These arteries are supplied by paired radicular arteries arising from the vertebral arteries and the aorta at each dermatomal level. At the lumbo-sacral region, at the level of the diaphragm, one of the intercostal arteries called **Arteria radicularis Magna (or Artery of Adamkiewicz)**. This artery arise at the level of T9-T12 in 60% of patients.

This artery may be damaged when the thoracic aorta is cross-clamped. So; the blood supply to the spinal cord may be seriously compromised causing paraplegia.

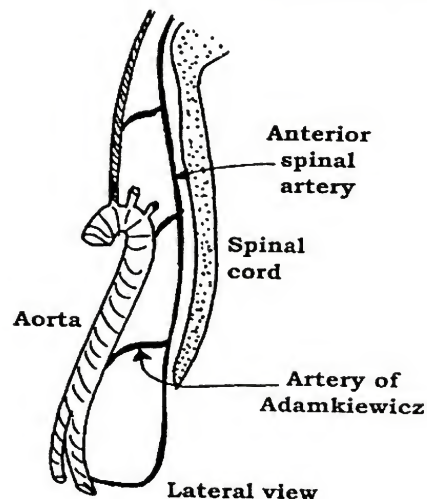


Figure 20-3; Blood supply of the spinal cord

ANESTHESIA FOR VASCULAR SURGERY

Management: spinal cord injury can be avoided by:

- 1) **Decreasing the time of clamping** to be < 30 min.
- 2) **Decreasing the complexity of surgical repair and dissection** (out of our control).
- 3) **A bypass or shunt** to maintain the distal aortic perfusion.
- 4) **Hypothermia:**
 - a- **Systemic Hypothermia:**
 - i) **Systemic Mild Hypothermia** (33 – 34° C):
 - By cooling blankets, cold i.v. fluids. It decreases the metabolic rate of the spinal cord which decrease ischemic injury.
 - ii) **Systemic Profound Hypothermia** (15- 19° C):
 - It causes circulatory arrest.
 - b- **Regional Spinal Cord Hypothermia:**
 - It is done by epidural cooling as an epidural catheter is inserted between T₁₁₋₁₂. A subarachnoid thermister catheter is placed at L₃₋₄.
 - Thirty minutes before aortic cross-clamping, iced (4° C) saline solution is infused into the epidural space via the epidural catheter till the CSF temperature reaches 25° C.
- 5) **CSF Drainage (Drainage of Spinal Fluid):**
 - Because aortic cross-clamping increases CSF pressure 3-5 mm Hg which decreases spinal cord perfusion pressure.
 - Recent studies do not show that CSF drainage is beneficial in preventing paraplegia
- 6) **Avoiding hyperglycemia:**
 - Because glucose on clamping (with hypoxia), causes anaerobic metabolism so, lactic acid is increased, increasing injury.
- 7) **Re-implantation of the intercostal and lumbar arteries:**
 - Preoperative identification of artery of Adamkiewicz is performed by selective angiography of intercostal arteries.
 - Arteries identified intraoperatively to be critical for spinal cord perfusion are re-implanted or preserved.
- 8) **Drugs:**

<ul style="list-style-type: none"> * Steroids. * Free O₂ radical scavengers. * Ca⁺⁺ channel blockers. * Intrathecal papaverine n * NMDA receptor antagonists. 	<ul style="list-style-type: none"> * Barbiturates * Mannitol (it decreases CSF pressure) * Tirilazad. * Fluosol DA (it is an artificial plasma substitute). * Mg⁺⁺
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3) Renal Protection:

Renal arteries arise from aorta at level of T₁₀-L₁ and may be higher at T₈.

a- In Thoracic Aortic Surgery**Or In Abdominal Aortic Surgery With Suprarenal Aortic Cross Clamping:**

There is a profound decrease in RBF (to about 90%). This produces irreversible renal ischemia resulting in acute renal failure.

- Protection is done by;

- 1- (1), (2), (3), (4) as **spinal protection with cold perfusion** of renal arteries.
- 2- Maintain **intravascular volume** guided by PCWP.
- 3- **Avoid distal hypotension** after aortic cross clamping.
- 4- **Avoid anesthetics which decrease RBF** as enflurane, isoflurane, desflurane and hypotension of regional anesthesia.

5- Drugs:

- **Dopamine** low dose 2-4 µg/kg/min.
- **Mannitol.**

• **Furosemide.**

b- In Abdominal Aortic Surgery With Infra-Renal Aortic Cross-Clamping:

- RBF decreases to a lesser extent (about 40%) but it also decreases CO which may be the cause of renal ischemia.

- Protection is done by;

1- Maintenance of CO as the primary goal.

2- Dopamine, mannitol as above.....

4) De-clamping of the Aorta:

- **Effects: De-clamping shock or release hypotension** occurs due to;

1- Sudden decrease in the afterload (de-clamping shock).

2- Reperfusion of lower parts of the body allowing acid metabolites to enter the circulation. This causes VD and metabolic acidosis.

3- Bleeding is maximal at this time as the adequacy of the vascular anastomosis is tested leading to severe hypotension.

4- Hypovolemia.

5- Reactive hyperemia.

6- Release of vasoactive substances.

7- Allergic reaction to graft materials.

- **Management:**

1- **Relative hypervolemia** is allowed during or just before de-clamping by fluid infusion to produce CVP 10- 12 cm H₂O (Increase CVP and PCWP just above normal values).

2- **Decrease the depth of anesthesia.**

3- De-clamping is done **slowly**, if severe hypotension is present;

- Ask the surgeon to constrict the aorta by his hand.

Or - Reclamp again.

This allows time for more fluid loading.

4- **Discontinue vasodilators and give vasopressors** e.g. phenylephrine 0.1 mg increment

5- **Correct metabolic acidosis** by NaHCO₃ if present.

6- **Superoxide dismutase** (a free radical scavenger).

5) Increased Intraoperative Blood and Fluid Loss:

- So, 1- Increase intraoperative fluid therapy 10-12 ml/kg/hr.

2- PCWP (more sensitive) and CVP monitor.

3- Adequate venous access.

4- Blood scavenging device (cell saver) for auto-transfusion.

6) Increased Heat Loss:

- Cause: • The patients are old with low metabolic rates.

• Extensive surgical exposure (of the bowel outside the abdomen) is present especially in abdominal aortic surgery.

- Management:

1) Warming of infused fluids.

2) Warming and humidifying of anesthetic gases.

3) Heat blanket.

4) Wrapping the bowel in a clear plastic bag.

5) Humid warm ambient atmosphere in O.R.

Extubation and Recovery:

- In long cases with great fluid shifts, extubate the patient after fulfilling the criteria of extubation. • Stable hemodynamic state.

• VC > 15 mL/kg.

• Maximum - ve inspiratory force < - 20 cm H₂O.

ANESTHESIA FOR VASCULAR SURGERY

- pH > 7.3
- PaO₂ > 60 mm Hg at FiO₂ < 50%.
- PaCO₂ < 50 mm Hg.

Postoperative Management:**In ICU****• Postoperative complications:**

- 1) Hypertension, hypotension, arrhythmias and heart infarction.
- 2) Hemorrhage.
- 3) GIT complications.
- 4) Paraplegia: (especially in thoracic aortic surgery)
- 5) Renal failure.
- 6) Respiratory failure.
 - Especially with trans-peritoneal approach with upper abdominal incisions.
- 7) Hyper-coagulable state which causes thrombosis of the vessels. It is decreased by combined epidural and GA.

• Postoperative analgesia:

- By 1) Neuro-axial (spinal or epidural opioids) ± local anesthesia.
- 2) Systemic opioids.
 - 3) NSAIDs.
 - 4) Transcutaneous electrical nerve stimulation (TENS).

N.B.: Emergency Aortic Surgery

Indication: Ruptured abdominal aortic aneurysm.

Anesthetic Management:

The same measures as above except.....

- 1) The patient is **grossly hypovolemic and the ABP is maintained only by the tone of abdominal muscles** (in abdominal aortic surgery) acting on the abdominal capacitant vessels.

Therefore; - Massive blood transfusion is needed.

- When muscle relaxant is used, sudden drop of ABP may occur.

So, immediate laparotomy and aortic clamping are needed.

- 2) **Induction of anesthesia** is only done **when the surgeon is prepared and the patient is ready for surgery.**
- 3) There is increased morbidity and mortality. The overall mortality from ruptured abdominal aortic aneurysm is 75 %.

Q: Discuss organ protection in aortic aneurysm anesthesia?

A: The following are protected; brain protection, spinal cord protection, heart protection, and renal protection.

CHAPTER 21

ANESTHESIA FOR CARDIAC SURGERY

Cardiopulmonary Bypass (CPB)

Extra-Corporeal Circulation (ECC)

- It is a technique that diverts venous blood away from the heart, adds O₂, removes CO₂ and returns the blood to a large artery. As a result, all blood flowing through the heart and most of that through the lungs ceases when CPB is fully established. The extracorporeal circuit is in series with the systemic circulation and provides both artificial ventilation and perfusion.
- Operation of the CPB machine requires a perfusionist (a highly specialized technician).
- Optimal results with CPB can be obtained only by close cooperation and communication between the surgeon, anesthesiologist and perfusionist.

Basic Circuit:

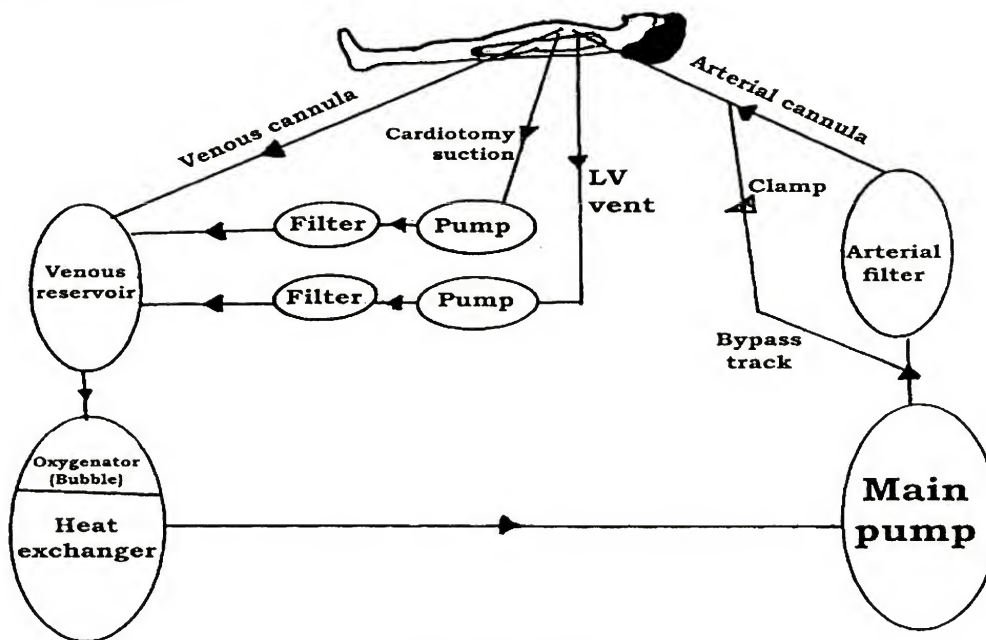


Figure 21-1; CPB

The Primary Fluid (and Hemodilution):

Volume:

Before the use of CPB, it must be primed with fluid devoid of any bubbles. The volume varies with the size of the oxygenator used and the tubing volume. It is usually 1500-2000 mL.

Type of Fluid:

- A balanced salt solution (or compound Na lactated solution) is generally used;
- + Other compounds are frequently added as;

ANESTHESIA FOR CARDIAC SURGERY

- 1- **Colloid** (albumin or hetastarch).
- 2- **Mannitol** (for renal protection) 200 mL 20%.
- 3- **Heparin** (to cover the thrombo-genic surface of the CPB circuit) 500-1000 units.
- 4- Bicarbonate.
- 5- K^+ (if cardioplegia will not be used).
- **Blood:** It is used in; - Small pediatric patients.
- Severely anemic adult patients.

Effect of Primary Fluid:

It produces hemodilution.

Advantages of hemodilution:

- 1- It increases the microcirculation due to decreased blood viscosity.
- 2- It decreases the metabolic acidosis.
- 3- It increases the UOP.
- 4- It decreases the blood demands.
- 5- It decreases the incidence of hepatitis, AIDs or reactions from blood transfusions.

Disadvantages of hemodilution:

- 1- It decreases the O_2 carrying capacity.
- 2- It causes postoperative EC fluid overload.
- 3- It increases the risk of pulmonary edema.
- 4- It causes hypotension from the decreased viscosity and peripheral resistance.
- 5- It decreases the concentration of Ca^{++} , Mg^{++} , phosphate and zinc.

Components of the Basic Circuit:**I) A Venous Reservoir:**

- It receives blood from the patient (usually from the right atrium) via one or two venous cannulas **by the effect of gravity**.

- Precautions:

- 1- Entrainment of air can produce an air lock that may prevent blood flow.
- 2- **The fluid level in the reservoir is critical.** If the reservoir empties, air can enter the main pump and causes **fatal air embolism** so, a low reservoir level alarm is typically present.

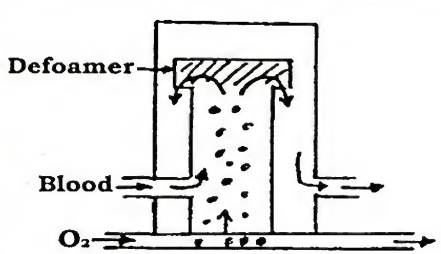
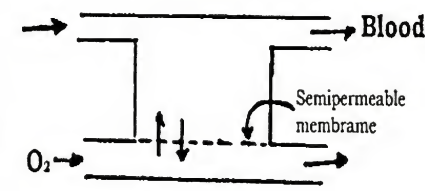
II) An Oxygenator:

- Blood is drained by gravity from the bottom of the venous reservoir into the oxygenator.

- Function:

- 1- The blood equilibrates with the gas mixture (primarily O_2).
- 2- CO_2 and volatile anesthetics are also frequently added at the oxygenator gas inlet.

- Types:

	Bubble Oxygenator	Membrane Oxygenator
		

Idea	<ul style="list-style-type: none"> - Tiny bubbles (foam) are formed as the O₂ passes through small holes at the base of a blood column. - Bubbles are then removed by passing blood past a de-foaming agent (a charged silicon polymer). 	<ul style="list-style-type: none"> - The blood gas interface is very thin. It is a gas-permeable silicon membrane through which O₂ diffuses.
Advantages	<ul style="list-style-type: none"> - Less expensive. 	<ul style="list-style-type: none"> - Less traumatic to formed elements in the blood so, it is preferred if a long bypass period is anticipated.
Disadvantages	<ol style="list-style-type: none"> 1- More traumatic to formed elements in blood (RBCs and platelets). This becomes more significant with longer period of bypass (> 4-6 hours), actually before 2 hrs no difference is noticed between the 2 types. 2- Increased risk of air embolism. 3- Protein denaturation. 4- Needs large priming fluid. 	<ul style="list-style-type: none"> - No risk of air embolism. - Expensive.

III) A Heat Exchanger:

The blood from the oxygenator enters the heat exchanger.

Function:


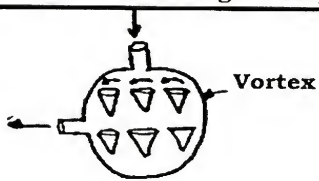
It either **cools or warms the blood** depending on the temperature of the water flowing through the exchanger (4 - 42°C) as heat transfer occurs by **conduction**.

IV) The Main Pump:

Types;

a- A double headed non occlusive roller pump.

b- A centrifugal pump.

	Roller Pump	Centrifugal Pump
		
Idea	<ul style="list-style-type: none"> - It produces flow by compressing a large bore tube in the main pumping chamber as the heads turn. - There is subtotal occlusion of the tubing to prevent excessive trauma to the blood elements. - It produces continuous non-pulsatile flow. Pulsatile flow can be produced in modified types (see later). - A greater risk of micro-air emboli. 	<ul style="list-style-type: none"> - It consists of a series of cones in a plastic housing (vortex). As the cones spin, the centrifugal forces created propel the blood from the centrally located inlet to the periphery. - There is no occlusion to the tubing so, it is less traumatic to the blood elements. - It produces continuous non-pulsatile flow. Pulsatile flow is not possible. - Less risk of micro-air emboli because small low density air bubbles are trapped in the center of the vortex.

The Pulsatile Pump:

Value: It is more physiologic (controversial).

- 1- It improves tissue perfusion.
- 2- It improves O₂ extraction.
- 3- It decreases the release of stress hormones.
- 4- It decreases SVR during CPB.

So, it increases renal and cerebral blood flow.

ANESTHESIA FOR CARDIAC SURGERYTypes:

- 1- **The modified roller pump:** by instantaneous variations in the rate of rotation of the roller heads.
- 2- **The ventricular type pump.**
- 3- **An indwelling intra-aortic balloon pump.**

V) An Arterial Filter:

A final in-line arterial filter (27- 40 μm) is used before the blood reaches the patient via a cannula usually in the ascending aorta.

VI) Accessory Pumps and Devices:**(a) Cardiomy Suction:**

- It aspirates blood from the surgical field during CPB and returns it to the main pump reservoir.

Or a cell-saver suction device is used: It aspirates blood from the surgical field during CPB and returns it to a separate reservoir. At the end of the procedure, the cell saver blood is **centrifuged, washed** and is given back to the patient.

(b) Left Ventricular Vent:

- With time, even after institution of total CPB, 2-5% of blood re-accumulates in the left ventricle due to;

- 1- Residual pulmonary flow from **physiologic shunts** i.e. from bronchial arteries (which arise directly from the aorta or the intercostals arteries), thebesian vessels (which drain blood directly from the heart to the its cavity) or pleural vessels. They end in the LA without passing via the lung.
- 2- **Aortic regurgitation** due to - Structural valvular abnormalities.
- Surgical manipulation of the heart causing functional AR.
- 3- **Extra-cardiac left to right shunts** e.g. patent ductus arteriosus, Blalock-taussig, Waterston, and Potts shunts.

Effect of LV distention:

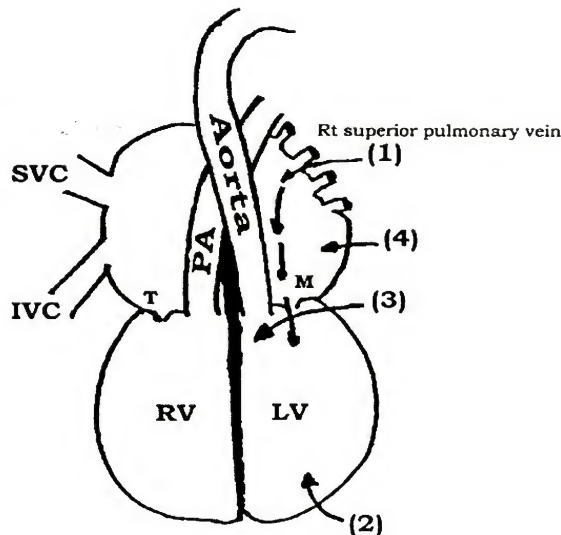


Figure 21-2; LV vent sites

- It **compromises myocardial preservation** and causes **post-pump HF** so, requiring decompression (venting).
- By: a catheter inserted into left ventricle at (figure 21-2);
 - The junction of the right superior pulmonary vein and left atrium then, advancing it via the left atrium and mitral valve into the left ventricle (the most common).
 - The LV apex.
 - The aortic root such as a cardioplegia cannula.
 - The pulmonary artery or left atrium only. Then the blood aspirated by the vent pump passes through a filter and is returned to the venous reservoir.

(c) Cardioplegia Pump:

- Cardioplegia is administered by either;
 - **An accessory pump** allowing optimum control over the infusion pressure, rate and temperature (by a separate heat exchanger).
- Or • A cold i.v. fluid bag which is **squeezed under pressure**.

(d) Hemo-Ultra-filter:

It consists of:

Hollow capillary fibers that can function as membranes, allowing separation of the aqueous phase of the blood from its cellular and proteinaceous elements.

Value: To increase the patient's hematocrit without transfusion.

Myocardial Preservation

A- Intentional Hypothermia:

Types and Values:

a- Systemic Hypothermia:

- It is produced by heat exchangers in the oxygenator.
- It **decreases the basal metabolic O₂ consumption** as metabolic O₂ consumption is generally halved with each 7-8 °C decrease in body temperature.

Temperature	°C	37	32	30	28	25	20	10
O ₂ Consumption	%	100	60	50	40	25-30	20	10

b- Topical Hypothermia: to reach a local myocardial temperature of 15-18 °C.

- It is produced by;
 - **Ice slush** in the pericardial sac and heart chambers if the heart is opened.
 - **Cold Cardioplegia.**
- It abolishes the energy expenditure associated with both electrical and mechanical activity. So, both **preserve the availability of high-energy phosphate compounds** thus, allowing **maintenance of normal cellular integrity and function** during CPB.

N.B.; **Hypothermia** (especially **mild**) produces **neuro-protection** as it protects against transient (but not permanent) ischemia because it decreases the cerebral metabolic rate and decreases the release of excitatory neurotransmitters, CAs or other mediators of cellular injury.

- Degree of Hypothermia (Systemic):

- Tepid hypothermia: 32-35 °C → It has recently been used.
- Mild hypothermia: 26-32 °C → It is the most common one used.
- Moderate hypothermia: 20-25 °C.
- Deep profound hypothermia: 15-19 °C.

Deep Profound Hypothermia: 15-19 °C.

- It allows total circulatory arrest up to 60 minutes.

ANESTHESIA FOR CARDIAC SURGERY

- It used for complex surgical repair, as during circulatory arrest both the heart and CPB machine are stopped. This allows the surgeon to remove the cannulas (which may have distorted the anatomy) and allows more precise repair of the lesion under optimal conditions i.e. a **bloodless and cannula-free field**.

- **Infants tolerate** hypothermic circulatory arrest **better** than older children and adults.

- Estimated safe periods of the circulatory arrest at different body temperatures.

Nasopharyngeal temperature	37°C	32	30	25	20	15
Estimated safe time	3-5 min	5-9	9-12	14-24	28-46	53-89

B- Potassium Cardioplegia:**- Action (Value):**

- It is a **chemical solution for arresting the myocardial electrical activity**.
- After initiation of CPB, induction of hypothermia, and aortic cross clamping, the coronary circulation is perfused with cold cardioplegia resulting in increased extra-cellular K^+ concentration. This increases K^+ shift intracellularly, so the trans-membrane potential is decreased (less -ve inside). This interferes with the normal Na^+ current during depolarization decreasing the rate of rise, amplitude and conduction velocity of subsequent action potentials. Eventually Na^+ channels are completely inactivated, action potentials are abolished and the heart is arrested in diastole.

- Components of K^+ Cardioplegia:

Although the exact composition varies from center to center, the essential elements of cardioplegia are the same.

Typical Components	Function and Comments
• K^+ < 50 (usually 20-40) mEq/L.	<ul style="list-style-type: none"> • The function of K^+ is as above..... • Avoid higher levels because they can be associated with a paradoxical increase in myocardial energy requirements and increase the K^+ loads.
• Na^+ 100-120 mEq/L.	<ul style="list-style-type: none"> • It is less than that of plasma because ischemia tends to increase the intracellular Na^+ content.
• Chloride 110-120 mEq/L.	<ul style="list-style-type: none"> • To maintain electro-neutrality.
• Ca^{++} 0.7 mEq/L.	<ul style="list-style-type: none"> • It acts as a membrane stabilizing agent. It stabilizes lysosomes and the cell membrane, maintaining cellular integrity.
• Mg^{++} 15 mEq/L.	<ul style="list-style-type: none"> • To control excessive Ca^{++} influx intracellularly so, relax the heart.
• Glucose 28 mmol/L (or glutamate or aspartate) + insulin.	<ul style="list-style-type: none"> • It acts as an energy substrate and improves intracellular shift of K^+.
• Bicarbonate 27 mmol/L (or histidine and tromethamine 'THAM' are alternative buffers).	<ul style="list-style-type: none"> • It acts as a buffer to increase the pH between 7.4 - 7.8 so, preventing excessive build up of acid metabolites due to ischemia, and increasing intracellular shift of K^+ because alkalotic perfusates are reported to produce better myocardial preservation.

- Vehicle of Cardioplegia:

a) **Crystalloid cardioplegia.**

b) **Blood cardioplegia:** It is used in **high risk patients**, where the components of cardioplegia are added to the blood.

Advantages: (controversial)

- 1- It **provides more O₂** as enough O₂ is dissolved in the plasma to sustain metabolism with little O₂ released from Hb during hypothermia.
- 2- It **decreases myocardial edema** due to the onconicity of the blood.
- 3- The presence of **RBCs enzyme catalase** may scavenge free radicals produced by ischemia.
- 4- Results of **clinical studies** show that blood cardioplegia **improves contractility** late in the postoperative course when compared with crystalloid cardioplegia.

- Method of Administration of Cardioplegia:

It is infused either by (figure 21-3);

- a) A small catheter **proximal to the cross clamping of the aorta**.
- b) Directly into the **coronary ostia** if the aorta is opened.
- c) Through the **aorto-coronary graft** if the surgeon elect to do the distal anastomosis first.
- d) **Continuous retrograde infusion** in severe coronary obstruction via a catheter in the **coronary sinus** into the coronary vein, because cardioplegia, if given by antegrade infusion, it may not reach areas distal to high-grade coronary obstructions (the areas that need it most).

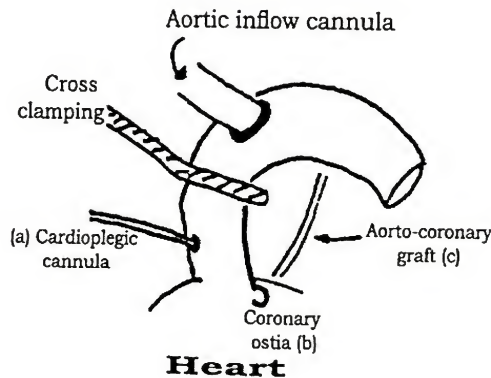


Figure 21-3; Method of administration of cardioplegia

- Dose of Cardioplegia: (15-20 ml/kg)

500-1000 mL is usually needed to paralyze the heart.

It can be **repeated several times (about every 30 minutes)** because of the gradual washout and rewarming of the myocardium.

- Temperature of Cardioplegia Solution

- a) **Cold Cardioplegia:** It is the most commonly used.

It is stored at **4 °C**.

- b) **Normo-Thermic (Warm or Tepid) Cardioplegia:**

- It has recently been used, It was started in the late 1980s and early 1990s.
- It is used at a temperature of **> 33 °C**. It is thought to be superior to cold cardioplegia, and it is given **continuously rather than intermittently**.

Physiologic Effects of CPB:

A) Hormonal Responses:

- Initiation of CPB causes a marked increase in stress hormones e.g. CAs, cortisol, arginine vasopressin and angiotensin due to;
 - Stress.
 - Decreased metabolism 2ry to;
- Hypothermia.
- Exclusion of the pulmonary circulation where many of these substances are normally broken down.

B) Humoral Responses:

CPB induces **coagulation/inflammation interaction** (coagflammation)

ANESTHESIA FOR CARDIAC SURGERY

- CPB induces coagulation and inflammation responses. It initiates a cascade of procoagulant and pro-inflammatory events.

- The mediators of coagflammation during CPB include:

Thrombin, cytokines, proteases, free radicals, arachidonic acid metabolites, platelet activating factor, nitric oxide synthesis/inhibition, endothelin, endotoxins, tissue factors, complement, adhesion molecules, extravascular leukocytes migration, kallikrein/bradykinin system, and selectins.

These mediators vary from organ to organ and patient to patient.

This is due to;

- Contact of blood with the internal surfaces of the CPB system.
- Mechanical trauma.
- A systemic inflammatory response syndrome (similar to that of sepsis and trauma) which can occur. If it is severe and prolonged, it produces;
 - Generalized edema.
 - Adult respiratory distress syndrome.
 - Acute renal failure.

C) Altered Pharmacokinetic Responses:

1- At the onset of CPB:

- Serum concentration of most drugs **acutely decreases** due to;
- Increased volume of distribution 2ry to hemodilution.
- Decreased protein binding.
- Some drugs as opioids also bind CPB components.

E.g. More muscle relaxants are needed.

2- During the course of CPB:

- Serum concentration of most drugs **acutely increases** due to;
- **Decreased hepatic and renal perfusion** which decreases the elimination of drugs.
- **Hypothermia** decreases metabolism.

N.B.; Hypothermia was thought to decrease the effect of non-depolarizing muscle relaxants because there is decreased cholinesterase enzyme activity. This increases Ach which competes with non-depolarizing muscle relaxants. Nowadays, it is believed that hypothermia decreases the doses of non-depolarizing muscle relaxants needed due to;

- Decreased metabolism.
- Decreased mechanical contractility of muscles.
- Drugs may **redistribute** from the peripheral to the central compartments.
- **Heparin** increases release and activation of **lipoprotein lipase**, which hydrolyzes the plasma triglycerides into free fatty acids. This causes **competitive inhibition to the drugs binding to plasma proteins**.

3- After CPB and postoperatively:

- Serum concentration of drugs is also **altered** due to alterations in α_1 -acid glycoprotein which changes drug binding.

Anesthetic Management of Cardiac Surgery

The anesthesiologist must follow the progress of the surgery intently & anticipate problems associated with each step because surgical manipulations often have a profound impact on circulatory function.

Anesthetic Management of Cardiac Surgery in Adults:

It includes:

A) Preoperative Management:

- Preoperative evaluation.
- Premedication.
- Patient preparation & monitoring.

B) Intraoperative Management:

- Induction of anesthesia.

- Maintenance of anesthesia.
- Prebypass period. - Hemodynamic changes.
 - Cannulation for CPB.
 - Bleeding prophylaxis.
 - Anticoagulation.
- Bypass period. - Initiation of CPB.
 - Pump flow & mean ABP.
 - Monitoring during CPB.
 - Myocardial preservation.
 - Ventilation of lungs.
 - Management of respiratory gases.
 - Fluid balance during CPB.
 - Cerebral protection during CPB.
- Termination of CPB. - Rewarming.
 - Evacuation of air.
 - Aortic cross-clamp removal.
 - Reinflation of the lung.
 - Monitoring.
 - Weaning from CPB.
- Postbypass period. - Reversal of anticoagulation.
 - Control of bleeding.
 - Removal of cannulas.
 - Continuation of patient warming.
 - Transportation of the patient.

C) Postoperative Management:

- Mechanical ventilation and extubation.
- Close observation of the patient.
- Fluid replacement.
- Postoperative analgesia.
- Postoperative complications.
- Anti-platelet therapy.

Preoperative Management:

1) Preoperative Evaluation and Assessment:

- The same as anesthesia with CVS disease see before.....
- + Body weight and height assessment is needed.
- + Assessment of other systems e.g. pulmonary, CNS, renal.....

2) Premedication:

1- Sedative Hypnotics:

- The most important thing is to make a **preoperative visit** to the patient for full explanation and reassurance.
- Generally,
 - Relatively **heavy premedications** are required for patients **with CAD**.
 - Relatively **light premedications** are required for patients **with valvular diseases** (who are often physiologically dependant on increased sympathetic tone).
 - **Decrease the doses of premedications** in patients with **poor cardiac reserve** or those with underlying **pulmonary disease**.
- O₂ supplementation 2-3 L/min via a nasal cannula is useful in avoiding hypoxemia after premedications.
- E.g.: • Midazolam 5-10 mg i.m, alone or + morphine 5-10 mg i.m.

2- Anticholinergics: are better avoided.

3- Preoperative therapy:

- **Digitalis: Stop digitalis for one half life before CPB** i.e. 1.5-1.7 days for digoxin or 5-7 days for digitoxin to avoid digitalis toxicity after CPB.
- **All anti-anginal and anti-hypertensive treatment** e.g. propranolol should be **continued till the time of surgery**.

3) Patient Preparation:

- 1- **The anesthetic plan** should be clearly prepared and should not be too rigid, so if a problem is encountered with one technique the anesthesiologist should be ready to change to another without delay.
- 2- **Adequate preoperative drugs and equipments** should be already prepared as there is little time intraoperatively to search for drugs or equipments. (Ideally one vasodilator and one inotrope infusion solution should be mixed and prepared for use before the start of the procedure).
- 3- The anesthesia machine, monitors, infusion pumps, and blood warmers should all be **checked** before the patient arrives.
- 4- **The cardioplegia solution** should be prepared and **stored at 4 °C**.
- 5- **Venous access:** While the patient is awake but sedated, **an O₂ mask or nasal cannula** is applied and the patient is connected to a **pulse oximeter**. Cannulation is done as follows;

a) Peripheral Vein:

- Using a **14 or 16 gauge** i.v. catheter (cannula).

b) Central Vein: (Sometimes it is inserted after induction of anesthesia)

- In internal jugular (or subclavian) veins by 2-3 single lumen 14-16 gauge catheters or multi-lumen i.v. catheters.

The lumen should be marked as;

- One i.v. port should be dedicated for drugs infusions and nothing else (to decrease the dead space).
- Another i.v. port for drug boluses.

And • Other i.v. port for CVP monitoring.

- 6- **Blood** should be **available** as an inadvertent injury of the right ventricle may occur during midline sternotomy especially if the patient has a previous midline sternotomy (i.e. **a redo**) because the RV may be adherent to the sternum.

4) Monitoring:

- Most monitors are applied before the induction of anesthesia because this period represents one of the major hemodynamic stresses of the procedure.
- The monitors should be displayed on a screen visible to both the surgeon and anesthetist.
- Monitors include;

1- A 5-Lead ECG: (Before induction)

- Combined **lead II and V5** are usually used.
- **Computerized ST segment analysis** is now available.
- **Baseline tracings of all leads** should be recorded on a paper for further reference.

2- ABP: (Before induction)

- a) **NIBP:** should be done for **comparison with invasive ABP**.

b) Invasive BP:

- Under local anesthesia while the patient is awake, by an arterial cannula in the radial artery usually, other sites e.g. ulnar, brachial, or femoral, can be used.
- Precautions: (if the radial artery is used).
 - Use the non-dominant hand (usually the left).

3- CVP Monitoring: (Before or after induction)

- Routine in all patients.
- Site: - Internal jugular vein is the preferred site for central venous cannulation.
 - Subclavian or external jugular veins. Especially on the left side are prone to kinking after sternal retraction.

4- Pulmonary Artery Catheter: (Before or after induction)

- It is **not routinely** used, only **indicated** in patients with;
 - **Compromised ventricular function** (ejection fraction < 40-50%).
 - Pulmonary hypertension.
 - Complicated surgical procedure e.g. combined CABG + valve disease.
- Data obtained: "see C.V.S monitoring".

5- UOP: (After induction)

- A urinary catheter is inserted after the patient is asleep.
- Sudden appearance of **red urine** may indicate excessive hemolysis due to;
 - CPB.
 - Or • A transfusion reaction.

6- Temperature: (After induction)

- Multiple probes are inserted after the patient is asleep.
- e.g. • Rectal or bladder temperature represent average body temperature.
- +• Esophageal or nasopharyngeal temperature represent core temperature.

N.B.; **Myocardial Temperature** is usually measured directly during CPB, **10-15 °C** is considered desirable.

7- Laboratory Monitoring: (After induction) It includes;

- AB gases, Hct, s. K^+ , Ca^{++} , glucose, and Mg^{++} .
- **Thrombo-elastography:** It assesses the visco-elastic changes in the blood during clotting.
- **Activated Clotting Time (ACT).**
 - Method: 2 mL of blood are put into a test tube containing celite to activate coagulation. The tube is kept at 37 °C and clot formation is watched or indicated by the presence of **a magnet in the tube** (which is fixed by the machine). The tube rotates in the machine so; on clot formation, the magnet rotates also stimulating an alarm. (**Hemochron apparatus**).
 - ACT is measured **before** heparin administration (baseline), **3-5 min after** heparin administration and **at a 30-60 min interval** thereafter.
- N.B.; ACT prolongation occurs within 1 min after heparin bolus injection, although the heparin peak action occurs 10-20 minutes after administration. This is because of an artifact from hemodilution and hypothermia which prolong the ACT.
- Value: - Normal ACT value = 105-167 sec (< 130 sec).
 - ACT after heparin should be > **480 sec**.
- A heparin dose-response curve can be obtained (see later).

8- Surgical Field Monitoring: (After induction)

- **Blood loss and surgical maneuvers** must be closely watched and related to changes in hemodynamics and rhythm.
- Once the sternum is opened, lung expansion can be seen via the pleura.
- Once the pericardium is opened, the heart (primarily the RV) is visible, so that the cardiac rhythm, volume and contractility can often be judged visually.

9- Trans-esophageal Echocardiography: (After induction)

- It gives information about **cardiac anatomy and function** during surgery.

10- Trans-cranial Doppler:

- To measure blood flow velocity in the basal arteries of the brain (usually the middle cerebral artery), via the temporal bone, to detect cerebral emboli.

Intraoperative Management:**Induction of Anesthesia:**

Only general anesthesia with controlled ventilation is used.

Slow smooth induction (cardiac induction) is indicated.

ANESTHESIA FOR CARDIAC SURGERYa) In patients with Good LV Function by:

Thiopentone 1-2 mg/kg (small dose), propofol, etomidate, or ketamine can be used.
+ Fentanyl 5-10 µg/kg.

b) In patients with Poor LV Function by:**A high dose of opioids.**

- ABP and HR are continuously evaluated after loss of consciousness.
- Avoid excessive pressor response or excessive hypotension.
- After induction, a nasal or oral airway, urinary catheter, rectal temperature probe and finally a tube is inserted.
- Muscle relaxants used are either;
 - Succinylcholine, if difficult intubation is suspected.
 - Non-depolarizing muscle relaxants. Use agents with little or no CVS effects e.g. rocuronium, vecuronium, doxacurium or pipecuronium.
- Pancuronium is of choice with high dose opioids due to its vagolytic effects which offsets the induced bradycardia.
- After intubation and controlled ventilation, baseline investigations are done as ACT (normal < 130 sec), AB gases, Hct, s. K⁺

Maintenance of Anesthesia:a) In patients with Relatively Good LV Function (i.e. EF > 40-50%)

Use **Inhalational agents** alone or with opioids.

- **Isoflurane** is of choice (although coronary steal may occur).
- **N₂O is avoided** due to its tendency to expand any intravascular **air bubbles** during CPB and if it is used, it should be discontinued 10-20 min before CPB.

b) In patients with Poor LV Function (i.e. EF < 40-50%)**High Dose Opioid** (is most commonly used):

- Mostly fentanyl or sufentanil ± a small dose of benzodiazepines or barbiturates
- E.g. • Fentanyl - For induction; 20-40 µg/kg i.v. slowly.
 - For maintenance; either - Additional boluses 5 µg/kg every 30-60 min.
 - Or - I.v. infusion 0.3-1.0 µg/kg/min.

- Advantages:

- It produces hemodynamic stability.

- Disadvantages:

1- **Patient awareness** is common so, concomitant use of benzodiazepines or low dose volatile agents are needed.

2- **Poor control of the hypertensive response** to stimulation.

So, add - Vasodilators (nitroglycerine or nitroprusside).

- β blockers (esmolol).

Or - Volatile agents.

3- Narcotic induced **bradycardia**.

4- Narcotic induced **muscle rigidity**.

So, muscle relaxants should be given as soon as consciousness is lost e.g. small dose pancuronium.

5- Narcotic induced **respiratory depression**.

It is not a problem because nearly all patients are ventilated postoperatively.

Prebypass Period: (i.e. after induction and before CPB)

Anesthetic problems include;

1- Hemodynamic Changes: due to

- **Periods of minimal stimulation** including skin preparation and draping so, hypotension occurs.
 - **Periods of maximal stimulation** including skin incision, sternotomy, sternal retraction, opening the pericardium and sometimes aortic dissection so, tachycardia and hypertension are produced. Adjust the anesthetic depth.
- N.B., During sternal splitting, stop ventilation and deflate the lungs to avoid lung injury.
- **Accentuated vagal responses.** Marked bradycardia and hypotension may occur during sternal retraction or opening of the pericardium especially if the patient is on β blockers, diltiazem or verapamil.
 - **Deeply anesthetized patients** have a progressive decrease in CO after the chest is opened due to decreased VR as the normally -ve intra-thoracic pressure becomes atmospheric so, this needs i.v. fluids.
 - **Myocardial ischemia** due to hemodynamic changes (increased or decreased ABP and HR) so, give a prophylactic nitroglycerin infusion 1-2 $\mu\text{g/kg/min}$ (controversial).

2- Cannulation for CPB:

a) Arterial (Aortic) Cannulation	b) Venous Cannulation
- Site: in the ascending aorta.	- Site: in the right atrium usually through the right atrial appendages.
- It should be done first (before venous cannulation) because: <ul style="list-style-type: none"> • Venous cannulation is associated with hemodynamic problems. • Rapid fluid infusion can be given via the aortic cannula to the patient if necessary. 	- It should be done after arterial cannulation.

3- Bleeding Prophylaxis:**1. Aprotinin (Trasylol):**

It is highly effective in decreasing perioperative blood loss and transfusion requirement by 40-80%. The exact mechanism is unknown but may be:

- 1- It is a non-specific inhibitor of serine proteases such as plasmin, kallikrin, and trypsin.
- 2- It preserves platelet function (adhesiveness and aggregation).

2. Tranexamic Acid:

It is less effective, and used instead of aprotinin.

3. Epsilon-Amino-Caproic Acid (EACA):

It inhibits plasminogen activation by binding to plasminogen, resulting in inhibition of 1ry fibrinolysis due to excessive plasminogen activators e.g. urokinase, tissue type plasminogen activator.

4. Intraoperative Normovolemic Hemodilution.**5. Intraoperative Plasma-pheresis.****4- Anticoagulation:**

- **Value:** It is done before CPB to:

- 1- Prevent acute disseminated intravascular coagulation.
- 2- Prevent formation of clots in the pump.

- **Method:** By Heparin given either by;

a- The anesthesiologist:

- 300-400 unit/kg (3-4 mg/Kg) via a central line.

• It is usually given while the aortic purse string sutures are placed during cannulation.

Or

b- The surgeon: directly into the right atrium.

N.B.; Heparin ampoule (1 mL) = 50 mg = 5000 IU.

- **Confirmation of the Adequacy of Anticoagulation:**

By: The Activated Clotting Time (ACT): (it is the one most commonly used)

ANESTHESIA FOR CARDIAC SURGERY

- It is measured **before heparin** administration to get a base line value.
- It is measured **3-5 min after heparin** administration.
- It should be **> 400-450 sec** (Most centers keep the ACT at **> 480 sec**)
- If it is **< 400 sec**, additional heparin 100 units/kg is given.

- Heparin Resistance:

Cause: It occurs in patients having; **anti-thrombin III deficiency** (acquired or congenital). N.B.; Anti-thrombin III is a circulating serine protease that irreversibly binds and inactivates thrombin and other active factors X, XI, XII, XIII. When heparin complexes with anti-thrombin III, the latter's anticoagulant activity is enhanced 1000 times so, anti-thrombin III is important for anticoagulation.

Treatment:

- Two units of fresh frozen plasma.
- Anti-thrombin III concentrate.
- Synthetic anti-thrombin III.

Then heparin can act easily.

- Patients with History of Heparin-Induced Thrombocytopenia (HIT):

There are two types;

Type I HIT	Type II HIT
<ul style="list-style-type: none"> • It presents in 10-20% of patients receiving un-fractionated heparin. • It occurs 1-4 days after heparin therapy and generally improves despite continuing heparin therapy. • It is a mild benign form of thrombocytopenia (rarely $< 100 \times 10^3/\mu\text{L}$). • Due to pro-aggregatory effects of heparin on the platelets. 	<ul style="list-style-type: none"> • It presents in less than <5%. • It occurs 5-10 days after heparin therapy. • It is a severe life-threatening condition with severe thrombocytopenia ($< 50 \times 10^3/\mu\text{L}$) with major thrombo-embolic processes (arterial thrombosis may cause limb ischemia, cerebrovascular stroke, or myocardial infarction). • Due to heparin dependent antibodies that agglutinate the platelets. The antibodies will bind to the complex formed between heparin and platelet factor 4 (PF4). This makes the platelets adhere, aggregate, and form platelets clots (white clots) which cause a thrombo-embolic phenomenon in 20% of patients.

Bypass Period**1- Initiation of CPB:**

After - The cannulas are properly placed and secured.

- The ACT is acceptable.
- The perfusionist is ready.

2- Pump Flow and Mean Arterial BP:**A) Pump Blood Flow:**

- It should be **> 70% of the CO** which is enough to maintain tissue oxygenation and perfusion.

- Adequate Values at Normal Temperature:

- **Adult:** 50-70 mL/kg/min.

Or 2.2-3.1 L/min/m².

N.B.; Normal CO = 70 mL/kg/min = 3.1 L/min/m² body surface area.

- **Pediatrics:** 100-150 mL/kg/min (higher due to higher metabolism).

Or 2.2-3.1 L/min/m² (the same as adult).

- Neonates: 150-175 mL/kg/min.

B) Mean Arterial Pressure (MAP)

- $MAP = \text{pump flow} \times SVR$.

With constant SVR, MAP is proportional to the pump flow.

Also, with a constant pump flow, MAP is proportional to SVR.

So, by controlling SVR and pump flow, MAP can be controlled.

- **MAP** should be maintained between **50-80 mm Hg**.

• At the Onset of CPB:

- The MAP usually decreases abruptly, and may reach **30-40 mm Hg** in the first 5-10 min of bypass due to;

- **Abrupt hemodilution** decreases blood viscosity which decreases SVR (this effect is partially compensated by hypothermia which increases blood viscosity again).

- **Inadequate pump flow at the beginning** of the bypass.

- **Hypoxic VD** from initial perfusion with blood free primes carrying no O_2 .

3- Monitoring During CPB:

- Beside the previous monitors, notice:

1) **CVP**: During the bypass period, it should be **low or zero** to make sure that there is no obstruction to the VR from the head.

2) **PAP**: During the bypass period, it should be **low or zero** to prevent over-distention of the left ventricle.

3) **UOP**: During the bypass period, it should be maintained **above 1 mL/Kg/hr**.

- Additional monitors are needed:

1) **The pump flow rate** should be **adequate** for tissue perfusion and oxygenation.

2) **The venous reservoir level**.

3) **Blood (perfusate and venous)**.

4) **Myocardial temperature**.

5) Inline (arterial and venous) O_2 saturation.

6) **Inline pH, CO_2 tension, and O_2 tension** sensors should be confirmed by a direct measurement.

N.B.: Criteria of inadequate flow rate (inadequate perfusion or hypoxia):

- Low venous O_2 tension < 40 mm Hg (N = 40-45 mm Hg).

- Low venous O_2 saturation < 70%.

- Progressive metabolic acidosis.

- Low UOP.

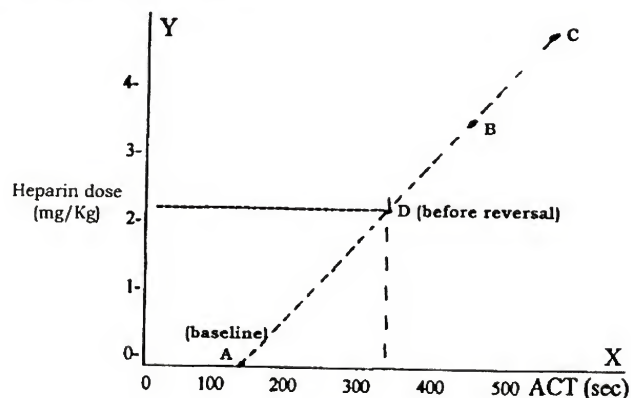
7) Serial ACT:

- It should be measured **immediately after the bypass**, then every 20-30 min thereafter, **extra-heparin** is needed if it is < 480 sec.

- **A heparin dose-response**

curve (figure 21-4) is often used to facilitate calculation of subsequent heparin doses and protamine reversal.

Although the relationship does not always conform to a linear function, it remains clinically useful.



A = Initial ACT

B = ACT after heparin dose

C = Desired ACT after the 1st heparin dose

D = Measured ACT before reversal

Figure 21-4; heparin dose-response curve

ANESTHESIA FOR CARDIAC SURGERY

1. Plot the initial ACT on the X axis (A) and the ACT after heparinization (B) and draw a line between (A) and (B).
2. If additional anticoagulation is needed, find the desired ACT on that line (C). The amount of additional heparin needed is the difference on the Y axis between the present ACT and the desired ACT.

3. For reversal of anticoagulation, measure the ACT before protamine is given (point D). The protamine dose is based on the remaining heparin activity.

8) **Serial Hct:**

It is usually kept between 20 and 25% so, RBCs transfusion into the pump reservoir may be needed.

9) **Serial s. K^+ , Na^+ and Ca^{++} :**

- Marked increase in s. K^+ 2ry to cardioplegia is usually treated with furosemide.

10) **Serial s. glucose:**

- It should be kept < 250 mg/dL.

- Avoid hyperglycemia as it may increase neurologic deficits, because under conditions of limited cerebral O_2 delivery e.g. during CPB, anaerobic glucose oxidation occurs to provide ATP which forms lactic acidosis. So, hyperglycemia by providing more glucose increases the degree of intracellular acidosis which increases the CNS insult.

4- Myocardial Preservation:

By hypothermia and cardioplegia see before.....

5- Ventilation of the Lungs:

- After initiation of full adequate CPB and the heart stopping to eject blood, **ventilation is stopped**. Premature discontinuation of ventilation will make any remaining pulmonary blood flow act as a right to left shunt causing hypoxia.

6- Management of Respiratory Gases:

- Hypothermia causes;

- Decreased $PaCO_2$ (and decreased PaO_2).
- Decreased H^+ (i.e. increased pH).

- Regardless of the patient's actual temperature, **blood samples are heated to 37 °C in the blood gas analyzer machine** before blood gases are measured so, blood gases are measured at a constant temperature of 37 °C.

The normal values at 37 °C are

- pH = 7.40 ± 0.05
- $PaCO_2 = 40 \pm 5$
- $PaO_2 = 95 \pm 5$

i.e. we compare blood gases at 37 °C

- There are 2 strategies for interpreting and managing blood gases during the hypothermia of CPB. Which is optimum? is still a **controversy**.

The normal patient's temperature is 37 °C
i.e. before hypothermia



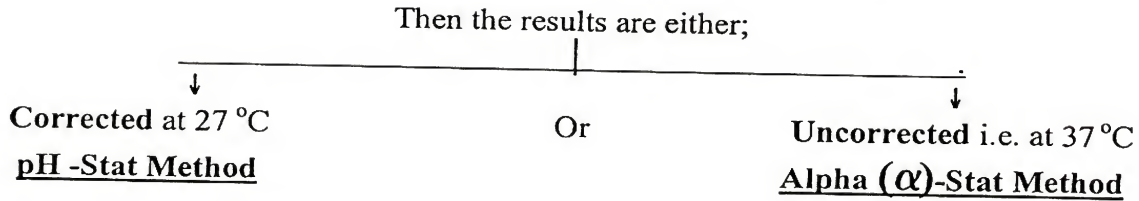
**During hypothermia, the patient's
blood sample is taken at 27 °C**



The Analyzer Machine

Which heats the sample to
37 °C

where measurement
of the pH and $PaCO_2$ are done.



7- Fluid Balance During CPB:

- During CPB, all i.v lines are shutoff.

- The intake (input) will include:

- The cardioplegic solution.
- Fluid or blood added to the venous reservoir during CPB.

The aim is to maintain a Hct of at least 18-20% during hemodilution

- The decreased blood level in the venous reservoir.

- The output includes:

- The UOP.
- The increased blood level in the venous reservoir.

8- Cerebral Protection During CPB:

1) Adjust the Pump Flow and MAP as before.....

2) Avoid Cerebral Emboli with CPB

- 1- Use membrane oxygenator instead of bubble oxygenators.
- 2- Use centrifugal pumps instead of roller pump.
- 3- Use filters in the suction line (to remove debris from the blood suctioned from the operative field) and in the arterial line (to remove accidentally introduced air, micro-bubbles or debris).
- 4- Meticulous removal of air before allowing the blood to be ejected from the left ventricle to the systemic circulation.
- 5- Minimal manipulations of the ascending aorta.
- 6- Temporary bilateral external compression of common carotid arteries by the anesthetist when ventricular ejection begins, may divert air and debris to other vascular beds.
- 7- Many clinicians advocate a head-down position while intra-cardiac air is being evacuated.

3) α-Stat (Temperature Un-corrected) Method is Preferable because it preserves cerebral autoregulation (CBF is coupled to CMRO₂).

4) Avoid Hyperglycemia During CPB:

Under conditions of limited cerebral O₂ delivery, anaerobic glycolysis becomes the 1ry method of ATP production leading to intracellular lactic acidosis. So, hyperglycemia provides more glucose for anaerobic glycolysis. This increases the degree of intracellular acidosis which correlates with the severity of subsequent cerebral injury.

5) Prophylactic Thiopental Infusion:

- Its use is controversial because, although it completely suppresses EEG activity, it may increase the need for inotropic support upon termination of CPB due to its cardiac action

6) Complete Circulating Arrest with Very Deep Hypothermia.

7) Others:

- Corticosteroids (methyl prednisolone 30 mg/kg).
- Mannitol 0.5 gm/kg.
- Phenytoin 10-15 mg/kg.
- Ca⁺⁺ channel blockers as Nimodipine.

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- N-methyl-D-aspartate (NMDA) antagonist (ketamine).
- Free radical scavengers.

9- Renal Protection During CPB:

The presence of post-CPB ventricular dysfunction and low CO is a major risk factor in the development of post-CPB renal dysfunction and failure. So; renal protection is done by;

1) Avoiding Oliguria:

- Oliguria is a sign of renal hypoperfusion and ischemia. Urine output (UOP) should be assessed every 15 minutes while on CPB. If UOP falls below 0.5 ml/Kg/hr, an action is necessary as follows;

- **MAP should be increased to at least 50 mm Hg.**
- If this fails to increase the UOP or the MAP is already optimized;
- Start diuresis with:

- **Furosemide:** 0.5-1 mg/Kg.

Or - **Mannitol:** 0.5-1 gm/Kg.

- Obligatory K^+ loss in the urine may result in hypokalemia before termination of CPB which may require K^+ supplementation.

2) Avoid and Manage Hemoglobinuria:

- Pink urine is a sign of massive hemolysis.
- Hemolysis is associated with the suction apparatus due to frothing, turbulence, acceleration, and sheer forces of -ve pressures.
- So; **maintain high output of alkaline urine by forced alkaline diuresis** to prevent renal tubule damage due to precipitation of acid hematin crystals.

Termination of CPB:

Separation from CPB should be gradual.

1. Rewarming:

- It should be **gradual**, usually takes **20-40 minutes** to re-warm a patient from 28°C to 35°C
- The rewarming should be **complete** i.e. esophageal or nasopharyngeal temperature should be at least 37°C.

Or rectal or bladder temperature should be at least 35°C before separation from the CPB.

2. Evacuation of Air from the Heart and any Bypass Graft:

- **Trans-esophageal echocardiography** is useful in detecting intra-cardiac air.

3. Removal of Aortic Cross-Clamp:

- Aortic cross clamping **can last for 60-120 minutes** with myocardial hypothermia and cardioplegia without coronary perfusion. The shorter the cross-clamping time, the better the myocardial function will be.

4. Resumption of Lung Ventilation:

- It must be started with **100% O₂**.
- Re-inflation of the lungs requires temporarily **higher than normal airway pressure** and should generally be done with **direct visualization** (or through the pleura) because overzealous lung expansion can interfere with internal mammary artery grafts.

5. Monitoring During Discontinuation of CPB: By;**1) Central Aortic Pressure:**

- It is **measured directly** and should be correlated to the radial artery pressure.
- It also can be estimated by **palpation, by the surgeon.**

2) Ventricular Volume and Contractility:

- It can be estimated **visually.**

3) Filling Pressure (from CVP and PAP):**4) CO Measurement:****5) Trans-esophageal Echocardiography (TEE):**

- It can provide valuable information about chamber volumes, contractility, and valvular function.

6) Laboratory Values:

- They must be within acceptable limits so; manage
 - Acidosis (if pH < 7.2).
 - Hypocalcemia (ionized).
 - Hyperkalemia (if > 5.5 mEq/L).
 - Hct should be 22-25%.

7) UOP and its Color:

- Observe the urine color for hemolysis due tosee before.
- Maintain the UOP for renal protection..... as before.

6. Weaning: It is accomplished by:

- Releasing the tapes around the vena cava.
- Progressively clamping the venous return line (tubing).
- As the beating heart fills, ventricular ejection resumes.
- **The pump flow gradually decreases as ABP increases.**
- Once the venous line is completely occluded and **systolic BP is judged to be adequate > 80-90 mm Hg**, the pump flow is stopped and the patient is evaluated. **ABP is the most easily measured index of successful termination of the bypass**, but ABP is a derivative of CO and VR so, if there is doubt regarding the pump efficacy, CO and VR should be measured.

- After coming off CPB, the patient is in one of 4 groups:

	I Vigorous	II Hypovolemic	III Pump Failure		IV Hyperdynamic
			A) LV Pump Failure	B) RV Pump Failure	
Ventricular function (can be assessed by direct vision)	Vigorous and good contracting heart.	Either; • Normal ventricular function. Or • Poor ventricular function (see below).	Sluggish, poorly contracting heart that progressively distends.		Good contracting heart and adequate volume.
Filling pressure	Normal	Low	CVP: N or High PAP: High PCWP: High	CVP: High PAP: N or High PCWP: N or High	Low
BP	Normal	Low	Low	Low	Low
CO	Normal	Low	Low	Low	High
SVR	Normal	High	High	N or High	Low
Treatment	- No treatment. - The patient can be separated immediately from the CPB.	- Volume replacement continues till the LAP is 12-15 mm Hg. - The patient can be separated from the CPB after volume replacement.	See below	Pulmonary VD + see below	1- Increase the Hct (as it is usually < 22%) by ultra-filtration (off CPB) or RBCs transfusion. 2- Vasoconstrictors 3- The patient can be rapidly separated from the CPB.

ANESTHESIA FOR CARDIAC SURGERY**- Treatment of Pump Failure (Group III):****1. Reestablish CPB.****2. Inotropic Therapy:** as

- Dopamine: most commonly used
- CaCl_2 : 0.5-1.0 gm i.v. bolus (the simplest).
- Dobutamine (it is commonly used).
- Amrinone or milrinone: Both are selective phosphodiesterase inhibitors.
- Epinephrine: The most potent inotrope.
- Glucose-Insulin-K (GIK) infusion is under research.
- Thyroid hormone (T_3): is under research.

3. Vasodilators: e.g. - Nitroprusside.

- Inodilator (as above).

They are used to decrease the SVR (if high).

4. Evaluate the Patient for Unrecognized Causes:

- Mostly by TEE.

- E.g. - Myocardial ischemia due to a kinked graft or coronary vasospasm.
- Valvular dysfunction.
- Shunting.

5. Circulatory Assist Devices:**a. Temporary Implantable Ventricular Assist Devices (VAD).****b. Intra-Aortic Balloon Counter-Pulsation (IABCP):**

- It is a catheter with a large balloon of 40-60 cc at its tip (figure 21-5).

- **Indications:** after CBP • If the inotropes and afterload reduction fail.

and • Before another attempt is made to wean the patient.

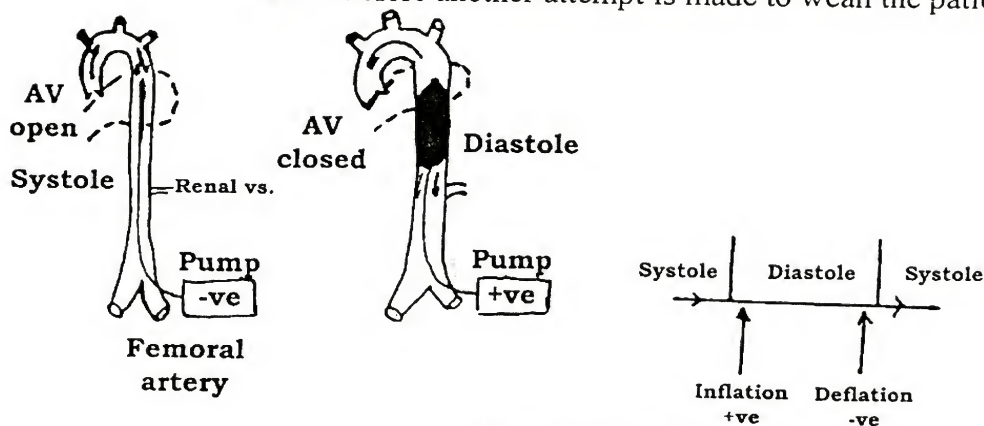


Figure 21-5; IABCP

Other Indications:

a) Ischemic Heart Diseases

- Acute myocardial infarction.
- During cardiac catheterization.
- Undergoing non-cardiac surgery.
- Failed PTCA and awaiting CABG.

b) Cardiac Surgery:

- Before CPB and postoperatively.
- After CPB-pump failure syndrome if other measures fail.

c) Pulsatile CPB, rare.**d) Pediatric congenital heart diseases.****e) Neurosurgery:** It temporarily increases CBF.

Technique:

- It is introduced through the femoral artery and positioned in the thoracic aorta just distal to the origin of the left subclavian artery and the balloon end rests proximal to the origin of renal vessels.
- Its efficacy is dependent on the proper timing of inflation and deflation.
- The balloon is **best inflated by helium or CO₂ gas just after the dicrotic notch**, after aortic valve closure i.e. **immediately after systole**, during the onset of diastole. This causes **diastolic augmentation** which;
 - Augments the diastolic BP by a retrograde flow towards the aortic valve that increases the coronary blood flow.
 - Displaces blood from the aorta that increases the peripheral blood flow.
- The balloon is best deflated maximally just before LV ejection i.e. **immediately before systole**, at the end of diastole. This;
 - Decreases the afterload by creating low pressure in the aorta (vacuum).
 - Augments the CO by 500-800 mL/min and increases contractility.
- IABCP is used in a frequency of 1: 1 to provide maximal support and the ratio is reduced to 1: 2 then 1: 3 during weaning (i.e. it is inflated and deflated every 3 intrinsic cardiac cycles).

Complications:

- Due to decreased CO: - Ischemia of the leg.
 - Splenic, mesenteric, and spinal cord infarction.
- Due to placement: - Dissection of the aorta.
 - Renal artery occlusion.
 - Internal mammary occlusion.
 - Inability to place the IABCP.
- Due to its material: - Thrombus formation and embolization.
 - Thrombocytopenia.
 - Infection.
 - Gas embolization.

Contraindications:

- 1- Aortic insufficiency.
- 2- Severe aortic disease e.g. atheromatous, aneurysmal, dissection, but still some use it in these conditions.

Q: What are the causes of hypotension when the patient is weaning from CPB?

A: Assess the pressure transducer at first. Then search for other causes as above (group II, III, IV).

Post-Bypass Period:

1- Reversal of Anticoagulation:

- By protamine

- Action: It is a highly +ve charged protein (a strong organic base poly-cation) that binds and effectively inactivates heparin (a highly -ve charged polysaccharide) (a strong organic acid poly-anion). So, heparin-protamine complexes are formed without anticoagulant activity i.e. heparin can not bind anti-thrombin III, which then is removed by the reticulo-endothelial system.

- Control:

- By repeating ACT 3-5 min after reversal as additional increments of protamine may be needed.
- Because heparin rebound is possible, ACT is repeated 20 min later. It is optimal to give protamine at 2 times after CPB (once after the bypass and again 1-2 hours later) to prevent heparin rebound. After initial reverse of heparin by protamine, the heparin which is sequestered in tissues is released slowly into the circulation where it can perform its anticoagulant function again.

- Dose: is calculated by one of the following methods:

ANESTHESIA FOR CARDIAC SURGERY

a) Based on the **heparin dose**:

- **1-1.3 mg protamine for each 100 units (1 mg) of heparin.**
- Only the initial dose of heparin is counted. The subsequently added doses of heparin required to keep the ACT level > 480 sec are not considered due to heparin metabolism and elimination.

b) Based on **heparin-dose-response curve**see above.

- Side effects:

1. **Excess protamine** (in a dose double than that used clinically) has an **anticoagulant action**.

2. **Hypotension**:

- Due to - **Acute systemic VD due to histamine release** on rapid injection of protamine (pharmacologic action).

- **Anaphylactic (IgE mediated) or anaphylactoid reaction** (immune or non immune idiosyncratic reactions).

- **Marked pulmonary VC** causes pulmonary hypertension leading to RVF.

- **Non-cardiogenic pulmonary edema** due to a delayed anaphylactoid reaction, as there are increased plasma levels of C_{5a} anaphylatoxins and thromboxane which cause pulmonary VC and bronchospasm.

2- Control of Bleeding:

- Causes of Persistent Bleeding and Oozing: (± clot formation)

1. **Inadequate surgical control of the bleeding sites**: (the most common):

Checking for bleeding especially from the **posterior surface of the heart** requires lifting the heart, which can cause severe hypotension.

2. **Inadequate reversal of heparin**: The ACT should return to the baseline after protamine, additional protamine (25-50 mg) doses may be needed.

3. **Re-heparinization (heparin rebound)**:

It occurs after apparent adequate reversal due to **redistribution**.

4. **Hypothermia < 35°C**:

It decreases platelet aggregation and number (i.e. thrombocytopenia) increasing hemostatic defects and should be corrected.

5. **Undiagnosed preoperative hemostatic defects** e.g. decreased vitamin K absorption from the GIT.

6. **Newly acquired defects**: E.g.

1) **Significant depletion of coagulation factors** (especially factor V and VIII) or **thrombocytopenia and platelet dysfunction**:

- Both are the most common recognized complications after CPB.

- Causes:

• Hemodilution.

• The foreign surfaces (the plastic, glass and metal) and blood-gas interface cause aggregation, adhesion and ADP release reaction of platelets, and clotting factors absorption, and protein denaturation.

• Trauma of platelets by the bubble type oxygenator is > with the membrane type oxygenator.

• The heparin used potentiates platelet aggregation and adhesions.

2) **Hypo-fibrinogenemia** (i.e. fibrinogen level < 100 mg/dL or prolonged thrombin time without residual heparin)

It is treated by cryoprecipitate.

3- Removal of Bypass Cannulas.

4- Continuation of Patient Rewarming:

After discontinuation of the pump, surface rewarming should continue as heat redistribution may occur resulting in hypothermia (i.e. after drop).

5- Patient Transportation: (from the OR to the ICU)

- Before the end of the operations the following **should be prepared**:

- Portable monitoring equipment, at least an ECG, invasive ABP, pulse oximetry, ± CVP.

- Portable infusion pumps.
- A full O₂ cylinder with a self-inflating bag.
- ETT, laryngoscope, succinylcholine, and emergency resuscitation drugs should also accompany the patient.
- **Sedation** by a small amount of opioid during transfer.

Postoperative Management:

1- Mechanical Ventilation (MV):

- Patients usually remain on MV for **2-24 hours postoperatively**.
- Extubation is only done when the **criteria of extubation** are fulfilled:
 - 1- Patients are **conscious** (awake and alert).
 - 2- Patients are **hemodynamically stable** with adequate peripheral perfusion, and UOP.
 - 3- **Acceptable blood gases** i.e. pH 7.35-7.45, PaO₂ > 80 mm Hg with FiO₂ 0.4, PaCO₂ 35-45 mm Hg.
 - 4- **Acceptable respiratory mechanics** i.e.
 - Vital capacity > 10-15 mL/Kg.
 - Tidal volume > 7 mL/Kg.
 - Maximal respiratory force > 20-25 cm H₂O.
- and **good muscle power**.
- 5- **Hemostasis** i.e. < 200 mL/hr chest tube drainage.
- 6- **Stable metabolic state** i.e. normal temperature and electrolytes.
- **Some centers do early extubation on the operating table or within 2 hours of surgery.**

This is called **Fast Tracking** provided that the criteria of extubation are met, but this demands changes in the technique as follows:

- 1) Cross clamping and bypass times must be **brief**.
- 2) **Intermittent cross-clamping with fibrillation** is used (i.e. warm) rather than cold cardioplegia and systemic hypothermia.
- 3) Anesthetic techniques include;
 - The use of relatively **small doses of fentanyl** (1.5-15 µg/Kg), alfentanil, sufentanil or remifentanil.
 - Pancuronium is replaced by **atracurium, or vecuronium**.
 - **Inhalational agents** as isoflurane or sevoflurane or i.v. agents as propofol are used for maintenance.

2- Close Observation of the Patient:

- For - Maintaining hemodynamic stability.
- Postoperative complications.

3- Fluid Therapy:

- It should be **guided by filling pressures**.
- Most patients require a good volume for several hours after surgery.

4- Postoperative Analgesia:

According to the anesthetic technique, timing of postoperative analgesia is determined by;

- I.v. opioids either bolus or infusion.
- Propofol infusion 1-2 mg/Kg/hr.
- **Regional techniques are not popular because coagulation defects** are common but, pre-bypass intrathecal opioid + postoperative epidural block have been reported.

5- Postoperative Complications (= Complications of CPB)

1- CVS:

- CHF.
- Arrhythmias.

ANESTHESIA FOR CARDIAC SURGERY

- Pump failure (low output) syndrome.
- Myocardial ischemia or infarction due to;
 - Surgical manipulation.
 - Prolonged CPB and aortic cross clamping (coronary ischemia).
 - Use of cardioplegic solutions.
 - Occlusion or kinking of grafts.
- Cardiac tamponade: needs urgent exploration even in the ICU.

2- Pulmonary:

- Adult respiratory distress syndrome due to;
 - Decreased blood flow to the lung during CPB.
 - Deflated alveoli during CPB which decreases the surfactant.
 - Fluid overloading.
 - Hyperoxia during CPB.
 - LVF.
 - Microemboli.

3- Renal:

- Polyuria due to hemodilution and diuretics.
- Oliguria due to hypoperfusion.

4- Postoperative Bleeding:

Causes: as before.....

So, monitoring of chest tube drainage is essential as;

- In the 1st 2 hrs, > 250-300 mL/hr (10 mL/kg/hr) is considered excessive
- After the 1st 2 hrs, > 100-200 ml/hr is considered excessive also.

Immediate sternotomy and exploration are essential.

Blood transfusion is usually needed if Hct becomes < 35%.

5- Embolism:

Due to air, destroyed or aggregated formed blood elements, fat, or endogenous debris.

6- Hyperglycemia:

Due to increased CA levels which inhibit insulin secretion and produce a direct action in the form of catabolism of glycogen in to blood glucose.

7- Hypokalemia and Hypomagnesemia:

Due to - Hemodilution.

- Diuretics used intraoperatively.

8- CNS:

- Neurologic complications occur in 40% of cases either;
 - **Transient neuro-psychiatric dysfunction** (the most common) ranging from subtle cognitive and intellectual changes to delirium and organic brain syndromes.
 - **Strokes** (less common) occurs in 2-5% of cases.
- Prophylaxis against strokes:.....see before.

Q: Discuss the hematologic aspect of cardiac surgery?

- A: 1-Bleeding prophylaxis.....see before.*
- 2- Anticoagulation.....see before.*
- 3- Reversal of anticoagulation.....see before.*
- 4- Causes of persistent bleeding and oozing after CPB.....see before.*

Q: Discuss the emergencies after cardiac surgery?

- A: • Weaning of the bypass; hypovolemic, pump failure, and hyperdynamic status.*
- Postoperative complications.....*

Anesthetic Management of Cardiac Surgery in a Pediatric Patient

As in **congenital heart diseases**.....mention them in details.

- 1- Obstructive lesions.
- 2- Left to right shunts.
- 3- Right to Left shunts.
- 4- Separation of the pulmonary and systemic circulation.
- 5- Mixing of the pulmonary and systemic circulation.

See anesthetic management for each in congenital heart diseases.....

Monitoring:

Before Induction

- Standard monitoring e.g. ECG, pulse oximeter, NIBP, and ETCO₂.

After Induction

- Invasive ABP.
- Central Venous Pressure.
- Pulmonary Artery Catheter.
- Trans-esophageal Echocardiography.

Cardio-Pulmonary Bypass

The same as that of adults except;

- 1- **Blood is used to prime the machine** for neonates and infants to prevent excessive hemodilution.
- 2- **CPB may be complicated by decreased MAP which decreases the systemic perfusion.**

Due to • Intra- and extra-cardiac shunts.

- Very compliant arterial system in very young patients.

So, - **Control shunts** as much as possible at the start of the bypass.

- Use **high flow rates** (up to 200 mL/kg/min) to ensure adequate perfusion in very young patients.

- 3- Surgical correction of **complex congenital lesions** may need complete circulatory arrest under deep hypothermia (**hypothermic circulatory arrest**). With a 15 °C core temperature, circulatory arrest up to 60 min is safe.

+ **Brain protection** by;

- Ice packing around the head.
- Mannitol 0.5 gm/kg.
- Methyl-prednisolone 30 mg/kg.
- Phenytoin 10 mg/kg.

CPB	Adult	Pediatric
• Perfusion pressure (MAP) (mmHg)	50-80	30-40
• Flow rates (mL/kg/min) at normothermia.	50-70	100-150
• Hemodilution.	+	++++ (if the priming fluid is not blood).
• Temperature.	28-32	15-20 in some cases
• Venous drainage problems.	Rare	Common
• Aortic cannula obstructing aortic outflow.	Not a problem	Common in small children due to the small aortic lumen
• Cannula placement technically.	Easier	More difficult

4- Weaning from CPB:

- It is usually easy and 1ry pump failure is unusual.
- Management of difficult weaning (if occurs).....as adult.

Extra-Corporeal Membrane Oxygenation (ECMO)

- It is a **prolonged extracorporeal CPB** achieved by extra-thoracic vascular cannulation.
- It is a modified heart lung machine **consisting of:**
 - 1- Distensible venous blood drainage reservoir.
 - 2- Roller pump.
 - 3- Membrane oxygenator: to exchange O₂ and CO₂.
 - 4- Heat exchanger: to maintain temperature.
- The patient must be maintained on **continuous heparin anticoagulation** to prevent thrombosis within the circuit.

Indications:

A) Cardiac Indications of CPB:

- 1- CABG.
- 2- Port-Access CABG (i.e. telescopic CABG).
- 3- Chronic constricting Pericarditis.
- 4- Valve replacement.
- 5- Congenital heart diseases.
- 6- Cardiac transplantation.
- 7- Post-cardiac arrest.
- 8- Surgical ventricular restoration surgery (Dor procedure).

B) Non-Cardiac Indications of CPB:

1) Persistent Fetal Circulation (persistent pulmonary hypertension of the newborn):

- Regardless of the 1ry cause which might be - 1ry persistent fetal circulation.
 - Congenital diaphragmatic hernia.
 - Meconium aspiration.
 - RDS.
 - Sepsis.
- It is used in patients who have potentially reversible underlying pathologic process (e.g. acute reversible respiratory or cardiac failure) not responding to the optimal ventilatory and maximal pharmacologic management.

2) Acute Respiratory Failure and ARDS:

- Regardless of the 1ry cause which might beSee causes of ARDS as before.
- It is used in patients who have potentially reversible underlying pathologic process not responding to the optimal ventilatory and maximal pharmacologic management.
- Value of ECMO in respiratory failure:

- **It reduces lung injury** associated with mechanical ventilation.
- O₂ and CO₂ gas exchange takes place during ECMO at ventilator settings that **rest the lung** (in newborns and adults).
- **Systemic perfusion is well supported.**

Its results in ARDs are not promising.

3) Liver Transplantation.....see before.

4) Renal Surgery: Renal cell carcinoma extending into the IVC or RA.

5) Pulmonary (Thoracic) Surgery:

- Left sleeve pneumonectomy with clamshell incision.
- Lung transplantation (single or couple).
- Broncho-pulmonary lavage in children for pulmonary alveolar proteinosis.

- 6) Neurosurgery for a huge aneurysm.
- 7) Tracheal Surgery:
 - A laryngo-tracheo-esophageal cleft.
 - Tracheal resection (especially carinal resection).
- 8) Vascular Surgery:
 - Advanced arterio-venous malformation.
 - Surgery on the descending thoracic and thoraco-abdominal aorta.
- 9) Shock:
 - Septic shock.
 - Cardiogenic shock.

10) Malignant Hyperthermia as a method of cooling.

Types of ECMO:

A- Veno-Arterial ECMO:

- It is the one most commonly used.
 - The venous catheter is threaded via the **right internal jugular vein** down to the **right atrium**. It is used for drainage as it carries blood to the oxygenator.
 - The arterial catheter is threaded via **the right common carotid artery** down to the **aortic arch** or **femoral artery**. It is used for re-infusion.
- Both vessels are ligated distally.

Advantages:

- 1- It **allows lung rest** from the harmful effects of excessive positive pressure ventilation (pulmonary barotraumas – O₂ toxicity).
- 2- It **diverts** as much as **80% of the CO** from the RA to the EC circuit **reducing** or eliminating the **right to left shunt** through a patent foramen ovale or patent ductus arteriosus which **closes** spontaneously during the course of ECMO.
- 3- It **decreases pulmonary blood flow and PAP** which decrease **right ventricular work**.
- 4- It **corrects arterial hypoxemia and acidosis** which decrease pulmonary vasoconstriction.
- 5- It allows **rapid growth of the hypoplastic lung** in patients with congenital diaphragmatic hernias.

B- Veno-Venous ECMO:

- The 1st venous catheter is threaded via the **right internal jugular vein** down to the **right atrium**. It is used for drainage as it carries the blood to the oxygenator.
- The 2nd venous catheter is threaded via **the right femoral vein**. It is used for re-infusion.
- Sometimes, a double-lumen polyurethane catheter is used for **single-site cannulation of the right internal jugular vein**.

Advantages:

- 1- It **allows lung rest** by reducing the motion of the diseased lungs and preventing their damage. This is accomplished by **low frequency positive pressure ventilation** + 3-5 sighs/min to preserve FRC.

Oxygenation is accomplished by **the lungs** while the EC circuit is used for CO₂ removal. This combination of low frequency ventilation and **CO₂ removal by ECMO** is performed at an EC blood flow rate of 20%-30% the CO.

Total gas exchange can be achieved by the veno-venous circuit (if the lung is non-functioning) by increasing the EC blood flow rate to 120% the CO.

- 2- **Maintenance of pulmonary blood flow.**
- 3- **Avoids the risks of arterial cannulation.**

ANESTHESIA FOR CARDIAC SURGERY**Complications of ECMO:**

After 20 days of ECMO support, the complications may exceed the potential benefits.

1- Mechanical: more common in adults.

- **Circuits - Clots** in the circuits.
 - Air in the circuits and **air embolism**.
 - **Cracks** or rupture in the connectors.
- **Malfunction** of the oxygenator, heat exchanger, hemo-filter or pump.
- **Vascular cannulas:** - **Mal-position** requires repositioning.
 - Unintentional **de-cannulation** or **kink**.

2- Patient complications: more common in children.

- **Bleeding:** (common)
 - **Intracranial bleeding** especially in • **Premature neonates** < 2 kg birth weight or < 35 weeks gestational age.
 - Patients with **recent head trauma**.
 - **GI and nasopharyngeal bleeding** are more common in adults.
- **Renal: Acute renal failure** (requiring dialysis or continuous hemo-filtration through the ECMO circuit).

Pericardial Diseases

Pericardial Effusion

- It is usually associated with acute pericarditis causing accumulation of the fluid in the pericardial sac.
- **C/P:**
 - a- **Acute** accumulation of fluid in the pericardial sac (even a small volume of 100-200 mL) increases the intra-pericardial pressure causing **cardiac tamponade** (see later).
 - b- **Chronic** accumulation of fluid causes stretch of the pericardium to accommodate the fluid up to large fluid volumes (1000 mL), without significant increase in the intra-pericardial pressure. So, pericardial effusion only (without tamponade) occur causing dyspnea.

Cardiac Tamponade

- **Pathology:**
 - There is accumulation of fluid (or blood) in the pericardial sac **under pressure** which increase the intra-pericardial pressure resulting in **impaired diastolic filling of the heart**. This decreases the SV resulting in hypotension and low CO syndrome. It increases the CVP.
 - In absence of severe LV dysfunction, equalization of the diastolic pressure occurs throughout the heart at **20 mm Hg**.
i.e. RAP = RVEDP = LAP = LVEDP.
- **Causes:** **Causes:**
 - **Infectious:** viral (the most common), bacterial, fungal, TB (usually with AIDs).
 - **Post-myocardial infarction (Dressler syndrome)**. It occurs after acute myocardial infarction by several weeks.
 - **Post-traumatic** e.g. cardiac surgery, pacemaker, intra-cardiac catheters or diagnostic procedures.
 - **Metastatic** diseases.
 - **Drug-induced** (minoxidil, or procainamide).
 - Mediastinal **radiation**.
 - **Systemic diseases** as rheumatoid arthritis, SLE, scleroderma, **uremia**.....etc.

- **Idiopathic** (the most common).
- **Postoperative after cardiac surgery.**
- **C/P:** A high index of suspicion is necessary;
- 1- **Increased CVP** causes;
 - **Kussmaul's sign** (especially if associated with constrictive pericarditis).
 - CVP waves show; - **No Y descent** due to impaired diastolic filling and atrial emptying.
 - **Normal or increased X descent** due to increased systolic atrial filling.
- 2- **Profound hypotension** which causes reflex activation of the sympathetic nervous system resulting in;
 - increased HR and peripheral VC to maintain CO (which is HR dependent).
 - Tachypnea.
- 3- **Muffled heart sounds.**

N.B.; **Beck's triad** = Neck vein distention, Hypotension, and Muffled heart sounds.

4- **Pulsus Paradoxus (Paradoxical Pulse):**

It is an accentuated drop in the systolic BP (> 10 mm Hg) and pulse volume with increased venous pressure (Kussmaul's sign) during inspiration, due to increased intra-pericardial pressure which exceeds the diastolic filling pressure of both ventricles (figure 21-6). Normally, during inspiration, there is a fall in the systolic pressure < 10 mm Hg and a fall in the venous pressure.

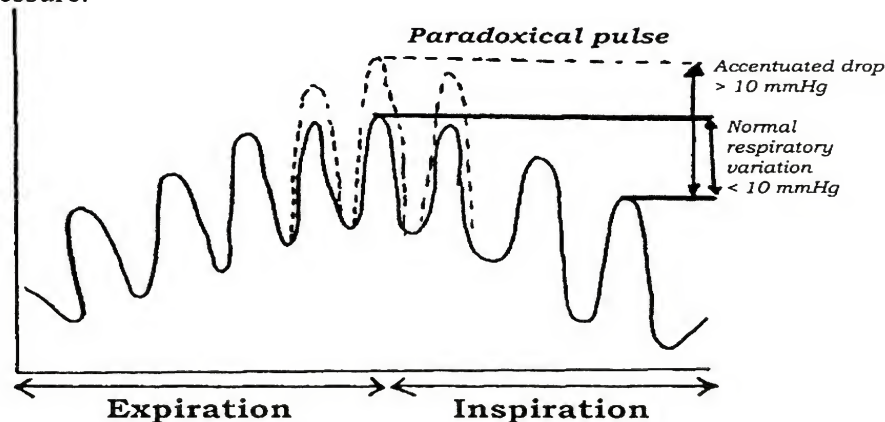


Figure 21-6: The paradoxical pulse

- **Investigations:**

1- **ECG:**

- **Decreased voltage** due to a short circuit effect of the pericardial fluid.
- **Non-specific ST segment and T wave changes.**
- **Myocardial ischemia.**

2- **Chest X-ray:**

- Cardiac size is **normal until 250 mL** of fluid is present in the pericardial sac.
- **Obscuration of the pulmonary vessels at the hilum.**
- A **globular or water bottle configuration** of the heart.
- Lungs are clear.
- Separations of epicardial and pericardial pads.

3- **Echocardiography.**

- **Treatment:** Drainage of pericardial fluid is done by either:

a- **Percutaneous Pericardiocentesis:** under LA

- The **16 gauge needle** (the needle over the catheter should be at least 15 cm long) is guided into the pericardial sac by **echocardiography** at either;

ANESTHESIA FOR CARDIAC SURGERY

- The left para-xiphoid area where the needle is directed towards **the tip of the left scapula at an angle of 45 degrees.**
- The left para-sternal 4th intercostal approach, where the needle is directed perpendicular to the skin (figure 21-7).
- Some prefer to use ECG monitoring of needle advancement by clipping the V lead to the needle. This technique is cumbersome and not often employed.
- **ECG monitoring** is essential.
- b- Surgical peri-cardiotomy:** under GA
- It is done via a left anterior thoracotomy or median sternotomy.

Anesthetic Management

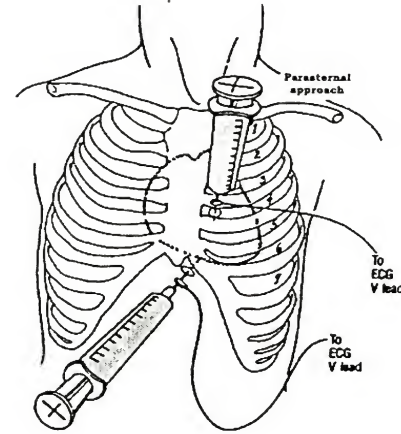
Preoperative Management

Patient Preparation

- 1- A large bore i.v. access is mandatory.
- 2- Temporary measures to improve hemodynamics include;
 - a- Expansion of the intravascular volume by colloids and crystalloids.
 - b- Inotropes: e.g. isoprenaline, dopamine or dobutamine.
 - c- Vasodilators e.g. nitroprusside or hydralazine could theoretically improve CO, but their use should be considered only when intravascular fluid replacement is achieved.
 - d- Correction of metabolic acidosis (which occurs due to the low CO).

It is treated by NaHCO_3 0.5-1 mEq/kg i.v.

Figure 21-7; Techniques for pericardiocentesis



e- Atropine:

To treat bradycardia which increases the CO, as it is HR dependent.

Bradycardia occurs due to vagal reflexes from the increased intra-pericardial pressure.

3- **Pericardiocentesis:**

It should be preformed under LA (\pm ketamine sedation) before GA is administered because **GA can cause severe hypotension and even cardiac arrest in patients with cardiac tamponade.** Then after the hemodynamic status is improved, GA and IPPV are applied to allow surgical exploration for definitive treatment of cardiac tamponade.

Intraoperative Management

Aim: to maintain the CO.

Monitoring:

Standard + invasive ABP and CVP.

Induction and maintenance:

- 1- **Ketamine:** for induction and maintenance.
 - It is a drug of choice because it increases myocardial contractility, SVR, and HR. N.B.; Ketamine in patients with a high sympathetic tone already produces intrinsic myocardial depression which decreases the CO and ABP.
- 2- **Benzodiazepines** e.g. diazepam for induction.
 - and N_2O for maintenance.
 - Muscle relaxant: **pancuronium** is the drug of choice.

Intraoperative Fluid: should be **generous** to maintain VR.

Postoperative Management

In ICU

CHAPTER 22

ANESTHESIA FOR THORACIC SURGERY

Physiologic Aspects During Thoracic Anesthesia

Three events affect thoracic anesthesia:

- Lateral decubitus.
- Open pneumothorax.
- One lung ventilation.

A) Lateral Decubitus:

a- In the Awake State (with Spontaneous Breathing):

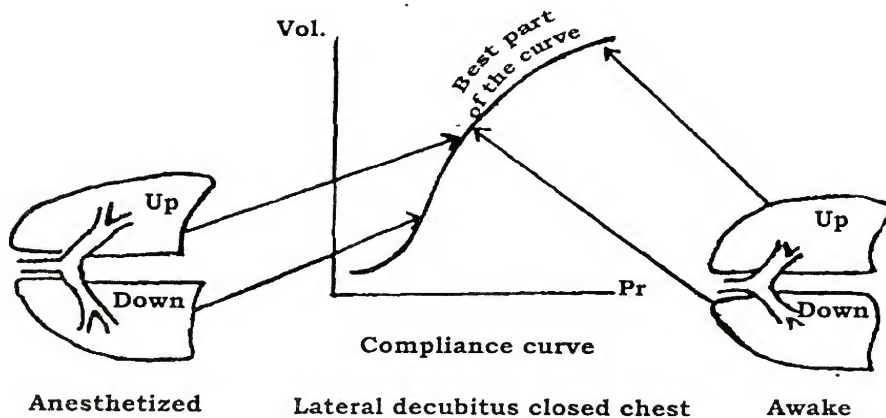


Figure 22-1; Lateral Decubitus

- There is **ventilation perfusion matching** (figure 22-1).

Because:

- The lower lung receives **more perfusion** due to the effect of **gravity**.
- The lower lung receives also **more ventilation** because contraction of the dependent hemidiaphragm is more efficient as it assumes a higher position in the chest by the abdominal contents (compared to the upper hemi-diaphragm which disproportionately shares in supporting the weight of abdominal contents). Therefore, the dependent lung is on a more favorable part of the compliance curve.

b- During General Anesthesia:

I) On Spontaneous Ventilation:

- There is **V/Q mismatching** because **anesthesia decreases the FRC** moving the upper lung to a more favorable part of the compliance curve, but moving the lower lung to a less compliant position. Therefore, the upper lung is ventilated more than the lower lung which has greater perfusion.

II) On +ve Pressure Ventilation:

- There is **further V/Q mismatching** because:

- 1- **IPPV** produces more ventilation in the upper lung because it is more compliant than the lower one.

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- 2- **Muscle paralysis** allows the abdominal contents to rise up further against the dependent hemidiaphragm producing further more ventilation in the upper lung and less ventilation in the lower lung.
- 3- Using a **rigid (bean bag)** to maintain the patient in the lateral decubitus position, further restricts the movement of the dependent hemithorax.
- 4- **Opening the nondependent side of the chest**, further increases the differences in compliance between the two sides, because the upper lung now is less restricted in movement.

B) Open Pneumothorax:

- Normally the lungs are kept expanded by a -ve pleural pressure (the net result of the tendency of the lung to collapse and the chest wall to expand).
 - **Opening one side of the chest** (or after chest trauma) causes **loss of the -ve pleural pressure** so, the elastic recoil of the lung on that side, causes **lung collapse**, with subsequent mediastinal shift and paradoxical respiration (figure 22-2).
- On spontaneous ventilation, progressive hypoxemia and hypercarbia occur.

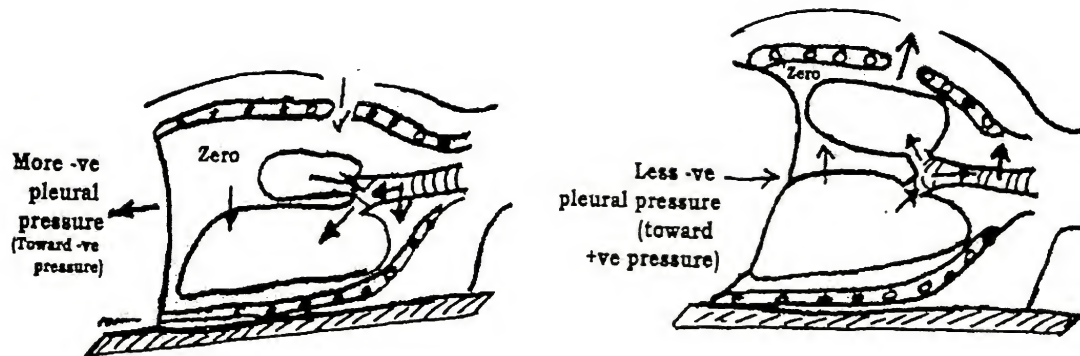


Figure 22-2; Open pneumothorax

1) Mediastinal Shift:

- During spontaneous ventilation in the lateral position;
- **Expiration** makes the pleural pressure less -ve (i.e. towards the +ve side) on the dependent side, but not on the open side (which is at a pressure of zero atmosphere) producing **upward shift of the mediastinum**.
- **Inspiration** makes the pleural pressure more -ve (i.e. towards the -ve side) on the dependent side, but not on the open side (which is at a pressure of zero atmosphere) producing **downward shift of the mediastinum**.

This shift decreases the contribution of the dependent lung to the tidal volume.

2) Paradoxical Respiration:

- During spontaneous ventilation in the lateral position, to- and fro- gas flow between the dependent and nondependent lung take place.
 - **Expiration** decreases the pneumothorax and allows the gas to flow from the dependent to the upper lung across the carina. This produces **outward movement of the rib cage**.
 - **Inspiration** increases the pneumothorax and allows the gas to flow from the upper lung to the dependent lung across the carina. This produces **inward movement of the rib cage**.
- Therefore, pendulum breathing or pendelluft is produced.**

- So, GA with IPPV should be applied to overcome these effects, as mechanical ventilation produces inflation of both the dependent and nondependent lung, decreasing the pneumothorax and increasing chest inflation during inspiration.

C) One Lung Ventilation:

During lung surgery, the more diseased lung is the one which will be upper most and collapsed i.e. one lung ventilation.

Indication:

a) Patient-related:

- To isolate the other lung - To confine infection to one lung.
 - To confine bleeding to one lung.
- To separate ventilation of each lung - Bronchopleural fistula
 - Tracheobronchial disruption.
 - Large lung cyst or bulla.
- Severe hypoxemia due to **unilateral lung disease**.

b) Procedure-related: to facilitate the surgical procedure:

- Thoracoscopy.
- Repair of thoracic aneurysm.
- Lung resection e.g. pneumonectomy, lobectomy, segmental resection.
- Esophageal surgery.
- Single lung transplantation
- Anterior approach to the thoracic spine.

Physiologic Effects of One Lung Ventilation:

a) Hypoxia:

- The collapsed lung is no longer ventilated, but still perfused so, there is a large right to left intrapulmonary shunt (20 – 40%) leading to mixing of unoxygenated blood from the collapsed upper lung with oxygenated blood from the ventilated dependent lung. In patients with normal lungs e.g. during esophageal surgery one lung ventilation produces a greater level of hypoxemia when a normal lung becomes collapsed (as this causes more V/Q mismatching). A diseased lung (even if it contains a focal lesion) tends to have a reduced blood supply, so when the diseased lung collapses during one lung ventilation, this causes less V/Q mismatching.

- **Fortunately blood flow to the upper non-ventilated lung is decreased by:**

- 1) Hypoxic pulmonary vasoconstriction (mainly) (HPV).
- 2) Surgical compression of the upper lung.

- **To Avoid Hypoxia:**see later.

b) Hypercarbia:

It does not occur usually because one lung ventilation;

- Decreases the dead space / tidal volume ratio increasing CO₂ excretion.
 - Increases the intrapulmonary shunt decreasing CO₂ excretion.
- So, the net effect is **unchanged CO₂ elimination**.

Techniques of One Lung Ventilation (OLV) include:

- A double – lumen Endobronchial tube.
- A single – lumen endotracheal tube with a bronchial blocker.
- A single – lumen endobronchial tube.

A) Double – Lumen Endobronchial Tube (DLT):

Advantages: It is the most commonly used due to.

- Its relative ease of placement.

ANESTHESIA FOR THORACIC SURGERY

- The ability of ventilating either one or both lungs.
- The ability of suctioning either one or both lungs.

Types: (Figure 22-3)

Name	Bronchus intubated	Carinal hook	Shape of Lumen
1. Robertshaw	Right or left	No	D-shaped
2. Carlens	Left	Yes	Oval
3. White	Right	Yes	Oval
4. Bryce-Smith	Left	No	Round
5. Bryce-Smith & Salt	Right	No	Round

Robertshaw type:

- It is the most common type used especially the **disposable** version
- It is available in different sizes

French → Internal diameter

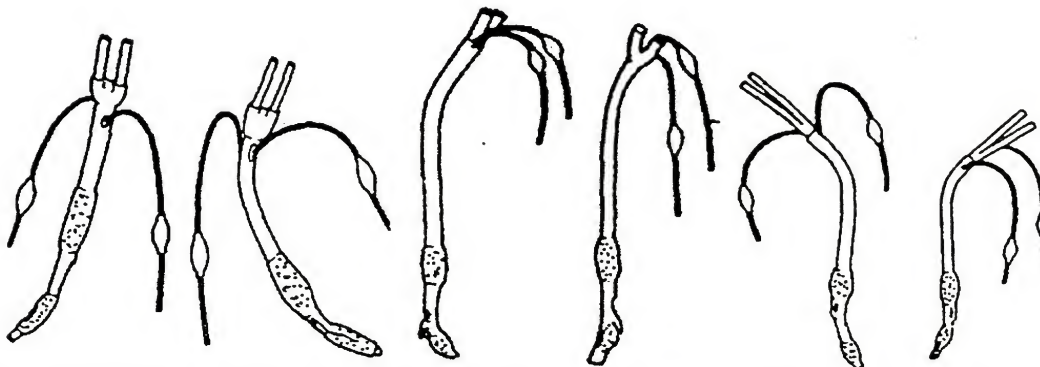
35 → 5.0 mm (the most common for a short female)

37 → 5.5 mm (the most common for a tall female)

39 → 6.0 mm (the most common for a short male)

41 → 6.5 mm (the most common for a tall male)

Recently, there is also, 26, 28, and 32 F.



Robertshaw (right)

Robertshaw (left)

Carlens

White

Bryce-Smith

Bryce-Smith and Salt

Figure 22-3; DLT

General Features: It has;

- A double-lumen (figure 22-4):
- A longer bronchial lumen which ends in either the right or left main bronchus.
- A shorter tracheal lumen which ends in the lower trachea.
- A **preformed curve** that allows preferential entry into either the right or left bronchus where;
- **Right-sided tubes** are designed for **left thoracotomies** (to ventilate the right lung and collapse the left lung).
- **Left-sided tubes** are designed for **right thoracotomies** or are used when **non-pulmonary surgery is undertaken**.

Most anesthetists use a **left sided tube** regardless of the operative side (right or left side).

- It has **2 cuffs**

- A **bronchial cuff** (1- 2 mL of air).

The right sided endobronchial tubes have

a **doughnut-shaped cuff which has a slit in**

- the **bronchial cuff** (figure 22-5) for ventilating the right upper lobe because the right upper lobe bronchus takes an origin usually 2- 5 cm from the right main bronchus which is the position of the bronchial cuff.

- A **tracheal cuff** (5-10 mL of air)

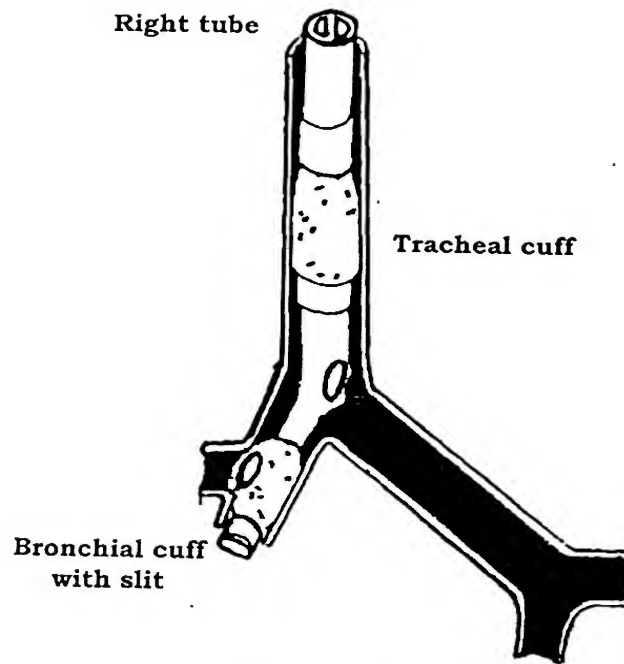


Figure 22-4; DLT

Confirmation of proper tube placement:

It should be done • **After tube placement immediately.**
 and • **After the patient is positioned for surgery.**

Confirmation is done by:

a) A preset protocol: (e.g. for left sided tubes)

1-Inflate the **tracheal cuff** (5 – 10 mL of air).

2-Check for **bilateral breath sounds**.

Unilateral breath sounds indicate that the tube is too far down (i.e. the tracheal opening is endobronchial).

3-Inflate the **bronchial cuff** (1 – 2 mL of air).

4-**Clamp the tracheal lumen.**

5-**Check for unilateral left sided breath sounds.**

- Persistence of right – sided breath sounds indicates that the bronchial opening is still in the trachea (i.e. the tube should be advanced).

- Unilateral right – sided breath sounds indicates incorrect entry of the tube into the right bronchus.

- Absence of breath sounds over the entire right lung and the left upper lobe indicates the tube is too low in the left bronchus.

6-Unclamp the tracheal lumen and **clamp the bronchial lumen.**

7-Check for **unilateral right breath sounds.**

- Absence or decreased breath sounds indicates that the tube is still not far enough down and the bronchial cuff is occluding the distal trachea.

b) A flexible fiberoptic bronchoscopy:

B) Single – Lumen Endotracheal Tube with a Bronchial Blocker:

- Bronchial blockers are inflatable devices which are passed alongside or through a single-lumen endotracheal tube (i.e. coaxially) to selectively occlude a bronchial orifice.

Types:

1) A Univent Tube:

- It is a single lumen-endotracheal tube **with a built-in side channel** (2 mm internal diameter) for a retractable bronchial blocker. It is commercially available (figure 22-6).

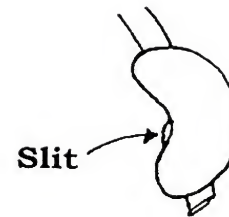


Figure 22-5; A bronchial cuff

ANESTHESIA FOR THORACIC SURGERY

- It is rarely used nowadays, may be in an **emergency as pulmonary hemorrhage.**

- Technique:

- The tube is placed with the blocker fully retracted.
- The bronchial blocker **must be advanced, positioned, and inflated under direct vision via a flexible bronchoscope.**

- Advantages:

- 1) A channel within the blocker allows the lung to **deflate** (though slowly) and can be used for **suctioning or insufflating oxygen.**
- 2) Unlike double lumen tubes, it **does not need to be replaced with regular E.T.T.** if the patient is to be left intubated postoperatively.

- Disadvantages:

The blocked lung collapses slowly (and sometimes incompletely) due to the small size of the channel within the blocker.

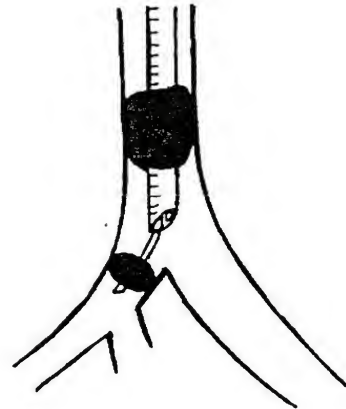


Figure 22-6; Univent tube

2) An Inflatable Catheter:

- E.g. **Embolectomy Fogarty catheter**, Swan Ganz catheter, or atrio-septostomy catheter.
- It can be used as a bronchial blocker in conjunction with a regular ETT (inside or alongside); a guide wire in the catheter can be curved to facilitate the placement.

- Disadvantages:

- 1- **It needs time and skill** for proper placement under bronchoscopic guidance.
- 2- It **does not allow suctioning or ventilation** of the isolated lung.
- 3- The catheter may **easily be dislodged** into the trachea leading to life threatening airway obstruction.

3) The Arndt Endobronchial Blocker (Wire-guided or Snare-guided endobronchial blocker "WEB"):

- It has recently been developed (figure 22-7).
- It is latex-free yellow colored with blue inflatable balloon.

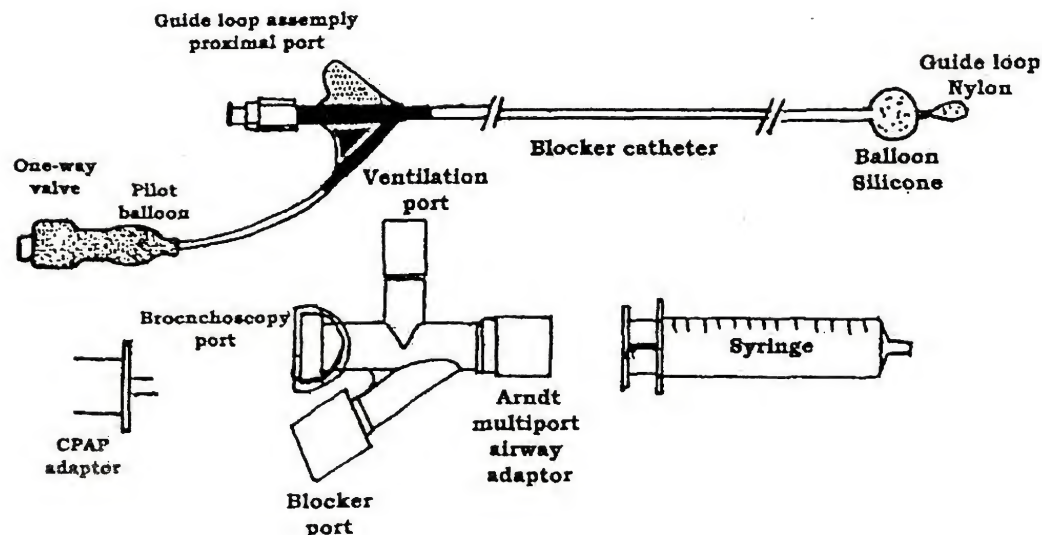


Figure 22-7; The Arndt endobronchial blockers

Technique:

- Once the patient's trachea is intubated with a single lumen ETT, the three-way adaptor can be connected and ventilation started.
- Then the blocker with its guide wire inside, can be passed through its port inside the single lumen tube i.e. coaxially.
- The bronchoscope is passed through its port inside the single lumen tube, within the wire loop of the blocker and then advanced to the position required to be blocked.
- After the desired location in the bronchial tree has been reached, the blocker is advanced over the bronchoscope. Then the wire loop and the bronchoscope are withdrawn to the trachea. The balloon is then inflated under direct visualization.

Advantages:

- Easily placed.
- Ability to use suction and apply CPAP to the blocked side.
- Not changed at the end of the operation with ETT.
- Used to do OLV via a nasal or tracheostomy tube.

C) Single – Lumen Endobronchial Tube:

It is rarely used nowadays. It is used only in **emergency cases e.g. unilateral pulmonary hemorrhage.**

Types:**1) Gordon – Green tube:**

Right sided single lumen tube for left thoracotomies as it is easily advanced to the right bronchus (figure 22-8).

- It has both **tracheal and bronchial cuffs** and a carinal hook.
- Inflating the bronchial cuff isolates and allows ventilation of only the right lung, while inflating the tracheal cuff (with deflating the bronchial cuff) allows ventilation of both lungs (although unequally).
- It has a much **larger slit** in the bronchial cuff (compared to right – sided double lumen tubes), leading to a high success rate in ventilating the right upper lobe.
- Disadvantages:
 - Risks of a carinal hook.
 - Inability to suction the left lung.

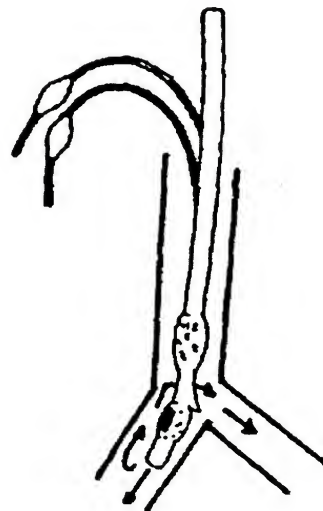


Figure 22-8; Gordon-green tube

2) Ordinary Uncut Single – Lumen Endotracheal Tube:

- It is the same size as that used for tracheal intubation (in infant, a smaller size by 1 mm ID is used).
- The tube can usually be advanced blindly into the right bronchus, if the source of the hemorrhage is the left lung, but usually the right upper lobe is not ventilated.
- The tube is difficult to be advanced blindly into the left bronchus, if the source of the hemorrhage is the right lung. This can be achieved by advancing the tube with its convexity posteriorly while turning the head to the right. If this is not possible, it must be guided by bronchoscopy.

Anesthesia for Thoracotomy

(E.g. Lung resection)

Preoperative Management:

1) Preoperative Assessment of the Respiratory System:

- Majority of patients have pulmonary diseases.
- The same as "anesthesia with respiratory disease".
- Prediction of operative risks and postoperative pulmonary complications after lung resection by; Preoperative Pulmonary Function Tests:
 - The degree of preoperative impairment of pulmonary function tests is directly related to the operative risk.
 - If preoperative pulmonary function tests are less than 50% of the predicted, this indicates high risk patients e.g. • $FEV_1 < 2 \text{ L}$.
 - $FEV_1 / FVC < 50\%$ of the predicted.
 - Maximum breathing capacity $< 50\%$ of the predicted.
 - $RV/TLC > 50\%$ of the predicted.

2) Preoperative Patient Preparation:

As with "Anesthesia with respiratory diseases" mention them +

- 1- Preoperative **patient nutrition and esophageal lavage** for cases of **esophageal surgery**.
- 2- Preoperative measures to **avoid DVT** e.g. low dose heparin.
- 3- Preoperative equipment for **airway management** should be available e.g. in addition to the basic equipments, variable sized single- and double lumen tubes, a flexible fiberoptic bronchoscope, a small diameter tube exchanger, CPAP delivery system and an anesthesia circuit adaptor for administering bronchodilators.
- 4- If epidural analgesia is planned postoperatively, it is better to put **the epidural catheter preoperatively while the patient is awake** as this decreases neurologic complications.
- 5- **Venous access:**
 - At least one large bore i.v. cannula (14 – 16 gauge) is mandatory.
 - Central venous access (preferably on the side of the thoracotomy), a blood warmer and rapid infusion devices are needed if extensive blood loss is anticipated.

3) Premedication:

1. Sedatives: no or minimal doses are given, if moderate to severe pulmonary disease is present.
2. Anticholinergics: e.g. atropine 0.5 mg i.m. or glycopyrrolate 0.2 mg i.m. are controversial as they are given to decrease the copious secretions, but inspissated secretions and bronchodilatation occur (increasing the dead space).

Intraoperative Management:

Monitoring: Standard +

- 1) **Non-invasive ABP:** It is measured from **the dependent arm**, if the patient is in the lateral position but this may be **unreliable** due to compression by the thorax.
- 2) **Temperature:** especially in **children** and adults, in **prolonged** procedures.
- 3) **Direct ABP** (and AB gases) are indicated in;
 - One lung anesthesia.
 - Resection of large tumors.
 - Any procedure in patients with limited cardiopulmonary reserve.
 - Expected severe hemorrhage.
- 4) **CVP:** The same indications as above.

5) PA catheter:

- Indications:
- Pulmonary hypertension.
 - LV dysfunction.
 - RV dysfunction (Corpulmonale).

Induction of Anesthesia**Smooth induction**

- Adequate preoxygenation
- Avoid the pressor response and bronchospasm of intubation so, deepen the anesthesia.
- Intubation is either by;
 - Ordinary ETT for most thoracotomies.
 - One lung ventilation in some cases.

Patient Position:

- After induction in the supine position, the patient is turned to;

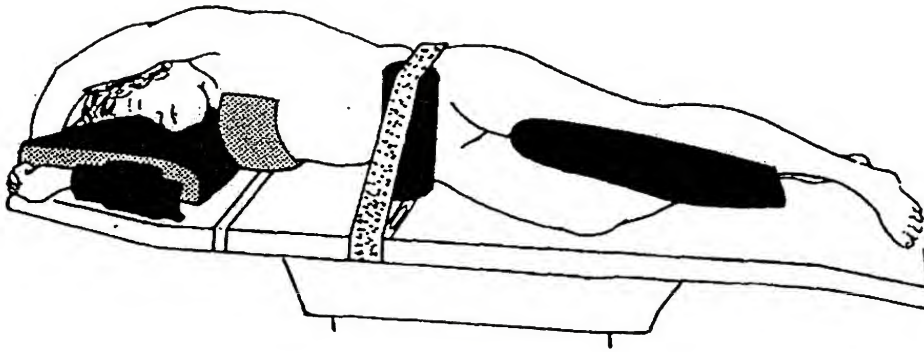
a) The Lateral Decubitus Position (figure 22-9):

Figure 22-9; Lateral position

- The patient is turned laterally with the diseased side uppermost.
- The lower arm is flexed while the upper arm is extended in front of the head pulling the scapula away from the operative field, with care to avoid nerve injury due to excessive traction.
- Pillows are placed between the arms and legs to prevent pressure damage. A cushion (axillary roll) is placed just under the dependent axilla to avoid injury to the brachial plexus.
- Care is taken to avoid pressure on eyes and ears.
- Physiologic effects of the lateral positionsee above.

b) Prone Position (Parry Brown Position):

- In some cases, it is preferred by some surgeons as it allows drainage of secretions from the diseased lung towards the trachea without soiling the other lung.

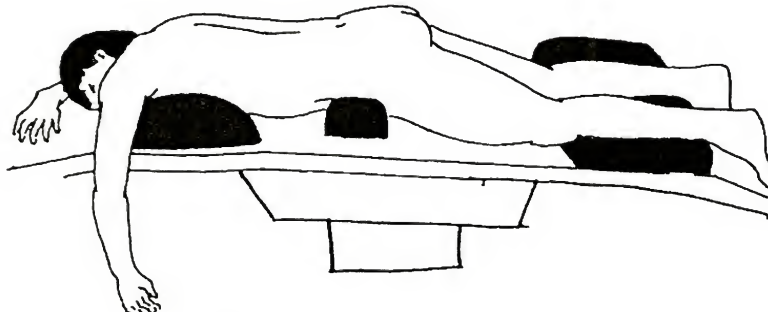


Figure 22-10; Parry Brown position

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- The shoulders and pelvis are supported to prevent pressure on the abdomen which increase intra-abdominal pressure impairing lung base expansion. This decreases the VR to the heart (figure 22-10).
- The arm on the operative side hangs over the edge of the operating table so that; the scapula is pulled away from the site of surgery.
- Physiologic effects of prone position.....see before Anesthesia for neurosurgery.

Maintenance:

$O_2 \pm N_2O$ + Volatile agents + Opioids + Muscle relaxant and CMV + Epidural analgesia.

- N_2O :

It is usually **avoided** because; - It causes an obligatory decrease in FiO_2 .

- It inhibits HPV.

- It increases the pulmonary hypertension in some patients.

If it is used, it should be only $\leq 40 - 60\%$.

- Volatile agents:

Advantages: • Potent dose-related bronchodilatation.

• Depression of airway reflexes.

• The ability to use high FiO_2 .

• The capability of relative rapid adjustments in the anesthetic depth.

• They have a minimal effect on HPV in doses < 1 MAC.

- Opioids:

Advantages:

1- Generally, minimal hemodynamic effects.

2- Depression of airway reflexes.

3- Residual postoperative analgesia.

- Muscle Relaxants and CMV:

• They are important in **preventing effects of open pneumothorax** (paradoxical breathing and mediastinal shift) "see above".

• **During rib approximation, hand ventilation** is helpful in avoiding injury to the lung parenchyma from suture needles after lobectomy or wedge resection if a single lumen tube is being used.

• Before completion of chest closure, **all the remaining lung segments** should be **fully expanded manually under direct vision**.

• CMV is then resumed and continued until chest tubes are connected to the suction.

Intraoperative Problems:1) One Lung Ventilation:

- At first two lung ventilation is maintained until the pleura is opened.

- Then one lung ventilation is applied to the dependent lung where the ventilation is adjusted to avoid hypoxemia and hypercarbia as follows:

• **Avoid high peak inspiratory pressure.** If it is increased > 30 cm H_2O ;

• Decrease the tidal volume to 8-10 mL/Kg.

and • Increase the respiratory rate to maintain the same minute volume and $PaCO_2$ of 35 ± 3 mm Hg because hypocapnia inhibits the HPV reflex in the non-dependent lung.

- Measures to treat hypoxemia if it occurs during one lung ventilation besides

• Keeping the period of one lung ventilation to a minimum.

& • Keeping FiO_2 to 1.0 (100% O_2).

1- Search for a possible cause: e.g.

• **Immediate re-expansion** of the collapsed lung should be done if hypoxemia persists.

- **Repeated fiberoptic bronchoscopy** through the tracheal lumen to **revise the position** of the endobronchial tube (or bronchial blockers) relative to the carina which can be changed as a result of surgical manipulation or traction.
- **Both lumens** of the tube should also be **suctioned** to exclude excessive secretions, or obstruction. If blood is present in the airway, instillation of 3- 5 mL of NaHCO₃ into the tube may facilitate the removal of clots.
- **Pneumothorax on the dependent ventilated side** should be considered. It usually occurs after extensive mediastinal dissection or with high peak inspiratory pressures.
- 2- Periodic inflation of the collapsed lung with O₂ i.e. **intermittent two lung ventilation**.
- 3- **Early ligation or clamping of the ipsilateral pulmonary artery** during pneumonectomy.
- 4- Give **5-10 cm H₂O CPAP** to the collapsed lung by **differential lung ventilation**, this is most effective when there is partial re-expansion of the lung which unfortunately can interfere with the surgery.
- 5- Give **5-10 cm H₂O PEEP** to the ventilated lung (it can be used with CPAP to the collapsed lung) by **differential lung ventilation**.
- 6- Continuous O₂ **insufflation into the collapsed lung**.
- 7- Changing the tidal volume and ventilatory rate.
- 8- Recently, **nitric oxide is used**. It causes **VD in the dependent lung** and so it increases the effect of the hypoxic pulmonary vasoconstrictive reflex in the non-dependent lung. This decreases the degree of the shunt.

2) Intraoperative Fluid Therapy:

- Opening of the chest causes **loss of the – ve pleural (intra-thoracic) pressure** which decreases VR. This is avoided by **i.v. fluid bolus**.
- **Generally**, i.v. fluids should be **restricted** in patients undergoing pulmonary resections as excessive fluid administration in the lateral decubitus position produces **lower lung syndrome** i.e. **gravity-dependent transudation of fluid** into the dependent lung. This increases intrapulmonary shunting and hypoxemia especially with one-lung ventilation.

Postoperative Management:

1) General Care:

- It should be in the ICU, usually overnight or for a longer time to detect postoperative complications and apply general care as:
 - Maintaining **semi-upright position** (> 30 degrees).
 - **Physiotherapy** to aid lung expansion and cough.
 - O₂ supplementation 40 – 50% (humidified).
 - Close hemodynamic and ECG **monitoring**.
 - Postoperative **chest X-ray**.

2) Extubation:

- Most patients are extubated.
- **If a double-lumen tube** was used for one-lung ventilation, it may be **replaced with a regular single-lumen tube** at the end of surgery. A **catheter guide (tube exchanger)** should be used if the original laryngoscopy was difficult.

3) Postoperative Analgesia:

1. Patient controlled analgesia.
2. **Injection above and below the thoracotomy incision** by:
3. **Intercostal block** by:
 - Local anesthetics.
 - Cryo-analgesia probe.

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4. Epidural narcotics (lumbar or thoracic).

5. Intra-pleural (inter-pleural) analgesia.

4) Postoperative Complications:

A) Respiratory Complications:

1- Postoperative Hypoxemia and Respiratory Acidosis: due to:

- Atelectasis.
- Shallow breathing 'splinting' due to incisional pain.
- Gravity-dependent transudation of fluid into the dependent lung.
- Preexisting lung disease.
- Accumulation of fluid and air in the pleural cavity.

2- Air Leak and Broncho-Pleural Fistula:

3- Torsion of a Lobe or Segment:

- It may occlude the pulmonary vein, with subsequent venous outflow obstruction leading to hemoptysis and infarction.

C) CVS Complications:

1- Postoperative supraventricular tachycardia.

2- Postoperative acute RVF.

3- Acute herniation of the heart into the operative hemithorax.

- C/P: • Sudden severe hypotension.
- Increased CVP (due to torsion of the venous input).
 - Ischemia and infarction.

4- Postoperative Hemorrhage.

D) Nervous System Complications:

1- Nerve injury: Extensive mediastinal dissection can injure;

* The phrenic nerve (or even the diaphragm itself) causing difficult weaning

* The vagus nerve.

* The left recurrent laryngeal nerve causing hoarseness.

2- Paraplegia: due to;

* Sacrificing (cutting) the left lower intercostal arteries producing spinal cord ischemia.

* Epidural hematoma if surgical dissection enters the epidural space through the chest cavity.

Special Consideration for Thoracotomies

1) Lung Tumors:

Anesthetic problems:

1- Respiratory affection as cough, hemoptysis, pneumonia, and pleural effusion.

2- Involvement of mediastinal structures with compression of;

- The recurrent laryngeal nerve causing hoarseness.
- The sympathetic chain causing Horner's syndrome.
- The phrenic nerve elevating the hemidiaphragm.
- The esophagus causing dysphagia.
- The SVC causing SVC syndrome.
- The heart causing epicardial effusion or cardiomegaly.

3- Secondaries in the brain, bone, liver, and adrenal gland.

4- Small cell carcinomas produce para-neoplastic syndrome

- Due to: • Ectopic hormone production.
- Immunologic cross-reactivity between the tumor and normal tissues.

- C/P:
- **Cushing's syndrome** due to ACTH secretion.
- **Hyponatremia** due to arginine vasopressin secretion.
- **Hypercalcemia** due to parathyroid hormone secretion.
- **Eaton-Lambert (Myasthenic) syndrome** due to antibody production.\
- **Migratory thrombo-phlebitis.**

2) Lung Infection:

Anesthetic Problems:

1- **Rapid sequence induction** with a **double-lumen tube** while the patient is in the **semi-upright position** with the affected lung in a dependent position **to prevent soiling of the healthy lung.**

2- **Repeated suction** is needed for the diseased lung.

3) Massive Pulmonary Hemorrhage: for tamponade.

- Definition: > 500-600 mL of blood loss from the tracheobronchial tree within 24 hrs.

Anesthetic Problems:

1) Emergency Measures as:

- **ABC protocol.....**
- **Multiple large i.v. cannulas.**
- **Maintain the lateral position** as much as possible with the affected lung in a dependent position **to tamponade the bleeding.**
- **A bronchial blocker or a Fogarty catheter** is placed.

2) Search for possible causes as T.B., bronchiectasis, or tumors after trans-bronchial biopsies. **Rigid or fiberoptic bronchoscopy** may be used.

3) Induction and intubation:

- **Preoxygenation** with 100% O₂.
- **Awake intubation** is preferred because patients usually **swallow** a large amount of **blood** and should be considered to have a **full stomach.**
- **Rapid sequence induction** in the semi-upright position and cricoid pressure by **ketamine and succinylcholine.**

4) One lung anesthesia is needed.

4) Pulmonary Cysts and Bullae: for resection.

Anesthetic Problems:

- Recurrent pneumothorax.
- They may rupture during anesthesia (especially if N₂O is used as it expands air spaces) causing **tension pneumothorax.**

5) Broncho-Pleural Fistula:

It is a connection between the tracheobronchial tree and the pleural cavity.

Anesthetic Problems:

- Assess for causes as:
 - **Post-pneumonectomy.**
 - **Rupture of a pulmonary abscess** into a pleural cavity.
 - **Pulmonary barotrauma.**
 - **Trauma.**
 - **Tumor.**
 - **Spontaneous rupture of a bulla.**
- There is a risk of **tension pneumothorax.**
- There is inability to effectively ventilate the patient with +ve pressure due to a large air leak via the fistula. If the chest tube drain is partially patent, it increases the intra-

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pleural pressure resulting in a risk of squeezing the tracheo-bronchial tree, so the other lung may be contaminated.

- Due to empyema, there is a risk of lung contamination on the other side, so **one lung ventilation** is necessary.
- Some recommend **awake intubation with a double lumen tube** (due to the presence of a large air leak) but **rapid sequence induction** is commonly used.

Anesthesia for Tracheal Resection

Anesthetic Problems:

- Preoperative :- The cause.
 - Tracheal (airway) obstruction.
- Intraoperative: - Intubation.
 - Ventilation during resection.
- Postoperative: - Patient position: flexed neck.

Anesthetic Management:

Preoperative Management:

1) **Preoperative assessment of the cause** by history, examination, and investigations e.g.

- **Tracheal stenosis** due to a penetrating or blunt trauma, prolonged endotracheal intubation or tracheostomy.
- **Tumors** especially squamous cell carcinoma, or adenoid cystic carcinoma.
- **Congenital anomalies.**

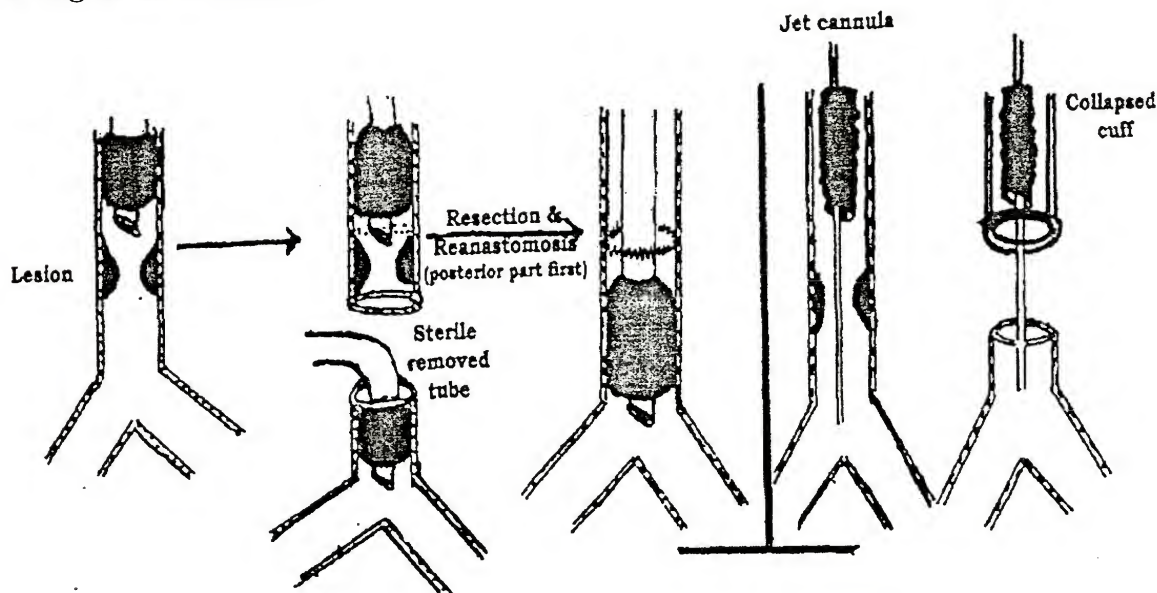


Figure 22-11: Ventilation during the tracheal resection

2) Preoperative assessment of the **degree of the tracheal obstruction.**

- **Progressive** airway obstruction causes dyspnea, wheezes, and stridor which increases on lying down and with exertion.
- **CT and chest X- ray.**

3) Premedications:

1. Sedatives: No or minimal sedation is needed as patients have a moderate to severe airway obstruction.

2. Anticholinergics: they are a controversial as they can dry secretions, but they make them inspissated.

Intraoperative Management:

Monitoring: Standard

Induction:

Slow inhalational induction (due to airway obstruction)

- With 100% O₂ and halothane (or sevoflurane).
- After the patient reaches deep anesthesia;
- The surgeon may do **rigid bronchoscopy** to evaluate and possibly dilate the lesion.
- **Laryngoscopy and intubation** is done with a suitable **small ETT** that can be passed distal to the obstruction whenever possible.

Maintenance:

As usual for general anesthesia.

Intraoperative Problems:

Ventilation during tracheal resection (figure 22-11).

A) For High Tracheal Resection:

1- Sterile Armored Tube:

- The surgeon divides the trachea in the neck below the lesion then advances a sterile armored tube into the distal trachea for ventilation during resection.
- After completion of the resection, the posterior part of the trachea is re-anastomosed first then the armored tube is removed and the original ETT is advanced distally to pass the anastomosis.

2- High Frequency Jet Ventilation:

- By passing a jet cannula beyond the obstruction into the distal trachea.

B) For Low Tracheal Resection via a median or right posterior thoracotomy.

1- High frequency jet ventilation.

2- Cardiopulmonary bypass.

Extubation:

Early extubation is desirable.

Postoperative Management:

The patient should be positioned with **the neck flexed**, immediately postoperatively, to decrease the tension on the suture line (figure 22-12).

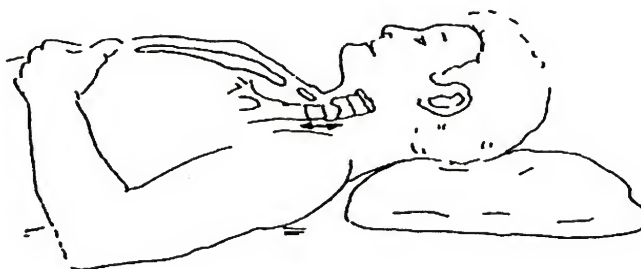


Figure 22-12; Postoperative patient position after tracheal resection

Anesthesia for Thoracic Telescopic Procedures

They include:

- 1- Thoracoscopy (Video – Assisted Thoracoscopy) (VAT).
- 2- Bronchoscopy (Fiberoptic and Rigid).
- 3- Mediastinoscopy.
- 4- Esophagoscopy (Fiberoptic and Rigid).

1) Thoracoscopy, Minimally Invasive Thoracic Surgery, or Video-Assisted Thoracoscopy (VAT):

Indications:

1. **Pleural diseases:** Pleurectomy and pleurodesis.
2. **Lung diseases:** Staging of tumors, biopsy, laser ablation of bullae, segmental or lobar resection, cyst removal, or abscess drainage
3. **Esophageal diseases:** Staging for tumors, vagotomy, or myomectomy.
4. **Mediastinal diseases:** Mass biopsy, or cervical sympathectomy for palmer hyperhydrosis
5. **Pericardial diseases:** Pericardiectomy.

Anesthetic Problems:

- 1) **Preoperative assessment and management of the lesion** e.g. pleural effusion, lung disease, airway obstruction.....etc.

- 2) **Anesthetic Technique:**

- **GA:** One lung ventilation by a double lumen tube to facilitate the surgery. It is the same as with open thoracotomy. It is indicated especially for **apical lung diseases**.
- **Local Infiltration:** It is used for minor procedures in some centers in spontaneously breathing patients, with propofol infusion as a sedation.
- **Regional Anesthesia:** as **thoracic epidural anesthesia + stellate ganglion block**

- 3) **Surgical Technique:**

- Surgeons should be **ready for immediate open thoracotomy** if necessary.
- **Partial collapse of the lung** on the operated side occurs by allowing **air to enter through one of the thoracoscopic ports into the pleural cavity**.
So, unlike laparoscopy, **there is no need for gas (CO₂) insufflation to collapse the lung** on the operated side because it is very dangerous. If the lung continues to be ventilated, very high intra-thoracic pressure during inspiration occurs leading to mediastinal distortion and CVS collapse.

N.B.; In very rare cases, CO₂ gas insufflation (**Capnothorax**) is needed when the lung on the operated side is not collapsed using a double lumen tube with the following precautions;

- The intra-thoracic pressure should be **< 6-10 mm Hg**.
 - The flow should be **< 2 L/ min**.
 - Both allow hemodynamic stability.
 - IPPV is mandatory.

4- Complications of OLV During Thoracoscopy:

- 1- The usual complications with any OLV.
- 2- Pneumothorax.

2) Bronchoscopy

Indications:

- a) **Diagnostic:**
 - Staging of bronchogenic carcinoma.
 - To obtain a biopsy.
- b) **Therapeutic:**
 - Removal of a foreign body (Rigid).
 - Insertion of an endobronchial stent (rigid).
 - Resection of an endobronchial mass e.g. laser.
 - To facilitate endobronchial intubation in difficult cases (flexible).

A) Fiberoptic (Flexible) Bronchoscopy:See air way management.

B) Rigid Bronchoscopy:**Anesthetic Problems:**

1- It needs **deep GA** using the standard techniques, but with **short acting muscle relaxants** as it is usually a short procedure (5 – 10 minutes).

2- **Ventilation:** By using 100% O₂ either.

a- Apneic Oxygenation:

- With a small catheter alongside the bronchoscope.

b- Side Arm of a Ventilating Bronchoscope:

- Conventional ventilation through the side arm of a ventilating bronchoscope which is connected to the breathing circuit.

c- Venturi-Jet (High Frequency) Ventilation:

- Though the injector type bronchoscope where a narrow cannula (16-18 gauge) in the proximal end of the bronchoscope is used to inject O₂ at high pressure, so a venturi effect is created proximally which entrains an air-O₂ mixture down the trachea.
- Disadvantages: There is a risk of barotrauma and anesthetic gas dilution.

d- High Frequency +ve Pressure Ventilation:

- At rates of 100 – 300 breaths/min (with +ve pressure).
- This technique eliminates air entrainment (i.e. no venturi effect) and allows ventilation with an undiluted anesthetic gas mixture.

e- Hayek Oscillator:

- Where an external – ve pressure ventilator (Hayek oscillator) is used.

3- **Complications** of bronchoscopy (especially the rigid type).

1. **Trauma** to:

- The teeth, lips, tongue, or oropharynx.
- The larynx or trachea causing postoperative laryngospasm and edema.
- Perforation of the airway causing mediastinal or subcutaneous emphysema.
- Pleural perforation causing pneumothorax.
- Pulmonary barotrauma with venture jet ventilation.

2. **Hypoventilation** causing hypoxemia, hypercarbia, and acidosis.

3. **Bradycardia and arrhythmias.**

4- **Postoperative care;**

- **Clear the airway** of secretions, blood, and debris.
- Keep the patient in the **left lateral head down** position till fully awake.
- Give **humidified O₂**.
- **Close monitoring** for laryngospasm and edema is mandatory.

Anesthesia for Esophageal Surgery**Anesthetic Management:****Preoperative Management:**

1- Preoperative assessment of **the esophageal lesion:** e.g. esophageal tumors, gastro-esophageal reflux, or systemic sclerosis (scleroderma).

- Dysphagia, coughing and/or wheezing on lying flat, heartburn, regurgitation, and aspiration (due to chronic obstruction) causing **recurrent chest infection**.
- **Anemia, weight loss, and cachexia** (especially in esophageal carcinoma).

2- Preoperative assessment of **other systems:**

- Smoking: Assess the presence of cancer esophagus, COPD, and CAD.
- Scleroderma: Assess the kidney, heart, lung, and Raynaud's diseases.

ANESTHESIA FOR THORACIC SURGERY**3- Preoperative Patient Preparation:****1. Measures against aspiration:**

As * Preoperative awake nasogastric suction.

* Antacids, H₂ blockers, metoclopramide, or omeperazole ...

2. Treatment of chest infections (if present).**3. Correction of anemia ± enteral or parenteral nutrition.****4. Measures against blood loss e.g. * Large bore i.v. catheters.**

* Prepare blood transfusion.

Intraoperative Management:**Monitoring:** Standard +

• Invasive ABP: It is done in patients when a great blood loss is expected.

• CVP: also done in patients when a great blood loss is expected.

• PA catheter: It is done in patients with cardiac problems.

Induction:

• **Rapid sequence induction** + cricoid pressure in the semi-upright position.

• **Awake fiberoptic intubation:** It is if difficult intubation is suspected.

• **Double lumen tube** (usually a left tube): It is used for procedures involving thoracoscopy or thoracotomy.

Maintenance:

Depends on * The patients hemodynamics.

* Associated diseases.

Intraoperative Problems:

1. The anesthesiologist may be asked to pass a **large diameter bougie** into the esophagus as a part of the surgical procedure. Great caution must be taken to avoid **pharyngeal or esophageal injury**.

2. **Great blood loss.**

3. **Intraoperative decreased body temperature:**

due to increased blood loss and lengthy surgery.

so, fluid warmer, forced air body warmer etc.

4. During the trans-hiatal approach:

The esophagus is freed up blindly by blunt dissection, the surgeon's hand transiently;

▪ interferes with cardiac filling producing **profound hypotension**.

▪ produces marked vagal stimulation causing **severe bradycardia**.

Extubation: Awake extubation

Postoperative Management:

In the ICU for major procedures.

1- Postoperative Ventilation:

For major procedures e.g. esophagectomy.

2- Postoperative Analgesia.**3- Postoperative Complications:**

• Pulmonary complications requiring postoperative ventilation.

• Injury to the phrenic, vagus, or left recurrent laryngeal nerve.

CHAPTER 23

ANESTHESIA WITH NEUROMUSCULAR DISEASES

Myasthenia Gravis

Cause: Autoimmune destruction or inactivation of postsynaptic **nicotinic acetylcholine receptors** at the neuromuscular junction (NMJ) by **antibodies** produced from T-cells of the thymus gland.

C/P:

A) Adult Type:

The onset occurs in **females** in the **3rd decades** and in **males** in the **6th – 7th decade**.

- **Course:** **Exacerbations and remissions** evoked by infections, stress, surgery, pregnancy, and drugs as aminoglycosides, colistin, polymyxin, quinidine, procainamide, lignocaine, penicillamine, phenytoin, lithium, and respiratory depressants.
- **Weakness of skeletal muscles is characterized by:**
 - **Asymmetric affection.**
 - Weakness occurs in a **descending manner**;
 - The eye muscles first resulting in;
 - **Ptosis** (the most common C/O). It is either uni- or bilateral, symmetric or asymmetric, and alternates between eyes.
 - **Diplopia** (the 2nd most common C/O).
 - Then **bulbar muscles** e.g. laryngeal and pharyngeal muscles resulting in dysarthria, dysphagia, problems of clearing secretions or pulmonary aspirations, nasal toned voice indicating palatal paralysis.
 - **Facial muscles** especially elevators of the angles of the mouth resulting in the characteristic "**Myasthenia Snarl**".
 - **Neck muscles.**
 - **Respiratory muscles.**
 - **Limb girdle muscles**, proximal then distal limb muscles.
 - **Trunk muscles.**
- The weakness **improves by rest** and **worsens by repeated effort** and at the end of the day.
- **Associated Autoimmune Disorders:**
 - Hypo- or hyperthyroidism.
 - Rheumatoid arthritis and systemic lupus erythematosus.
 - Myocarditis resulting in cardiomyopathy, AF, or heart block.
 - Thymic enlargement (especially thymoma) in 70% of the cases.

B) Juvenile Type:

- It occurs before **2 years of age** and is confined to **bulbar muscles**.

C) Neonatal Type:

- It occurs in **babies of myasthenic mothers** who may show transient myasthenia for 1- 3 weeks and may need mechanical ventilation due to placental transfer of antibodies.

ANESTHESIA WITH NEUROMUSCULAR DISEASES

Differential Diagnosis:

(1) Myasthenic crisis and cholinergic crisis: Both are muscle weakness emergencies.

	Myasthenic crisis	Cholinergic crisis
Cause	- Exacerbation of myasthenia due to inadequate treatment, drug- induced infection...	- Excessive anticholinesterase treatment.
Edrophonium test.	- Improvement occurs.	- Worsening occurs.
Muscarinic symptoms	- Absent e.g. pupil diameter is > 3mm	- Present e.g. miosis, salivation, bradycardia, diarrhea, sweating...
Treatment	1) Anticholinesterase + atropine. 2) Mechanical ventilation. 3) Antibiotic for infection. 4) Plasmapheresis.	1) Stop anticholinesterase + atropine. 2) Mechanical ventilation. 3) Pyridostigmine (PAM) 500 mg i.v. infusion.

(2) Myasthenic syndrome (Eaton- Lambert syndrome)..... see later.

(3) Other diseases e.g. thyrotoxicosis, neurasthenia, progressive external ophthalmoplegia muscular dystrophies, brain tumors, and amyotrophic lateral sclerosis.

Diagnostic Tests:

A- Electro-Physiologic Tests:

1. Peripheral Nerve Stimulator:

- Electromyography shows a **rapid decrease in the amplitude** of the compound action potential, evoked during **repetitive stimulation** of a peripheral nerve.
- The sensitivity of this test is 50-70%.

2. Stapedius reflexo-metry.

3. Nystagmography.

B- Pharmacologic Tests:

Edrophonium Test: 10 mg i.v. cause a dramatically improved response.

C- Serologic Tests:

Detection of Antibodies:

They are present in patient's serum in 80-95% of cases.

Treatment:

1) Anti-cholinesterase Drugs:

- It inhibits breakdown of Ach by tissue cholinesterases increasing Ach at NMJ.

e.g. • **Pyridostigmine (Mestinone):** It produces less muscarinic effects.

Dose: 60-120 mg oral every 4-6 hours.

2 mg i.v. / i.m. every 6 hours.

• **Neostigmine (Prostigmine):** It produces greater muscarinic effects.

Dose: 15 mg oral every 6 hours.

1.5 mg i.m. every 6 hours.

0.5 mg i.v. every 6 hours.

+ **Atropine or propantheline (vagolytic) are used to block muscarinic effects.**

2) Immuno-Suppressive Drugs: To decrease antibody production.

e.g.: • **Corticosteroids** as prednisolone 10 mg/day (it is used with anti-cholinesterases).

- Also methotrexate, cyclo-phosphamide, zathioprine, or ACTH are used in severe cases.

3) Plasmapheresis:

- To **remove antibodies** as an emergency treatment or during preoperative preparation. It produces unpredictable response.

4) Thymectomy:

- For patients < 40 years old with thymoma. Improvement occurs in 50% of patients.

Anesthetic Management:**Preoperative Management:****1) Preoperative Assessment of Muscle Weakness:**

- Bulbar muscle weakness causes problems of clearing secretions or pulmonary aspiration.
- Respiratory muscles causes difficult breathing.
- Preoperative predictive criteria for postoperative ventilation are assessed.
- Edrophonium test to exclude cholinergic crisis.

A Scoring System by Leventhal, Orkin, and Hirsch is assigned:

- Duration of the disease > 6 years —————→ 12 points.
- History of COPD —————→ 10 points.
- Pyridostigmine dose > 750 mg/day (in the day before surgery) → 8 points.
- Preoperative vital capacity < 2.9 liters —————→ 4 points.

Patients with a score < 10 points, could be extubated immediately postoperatively.

Patients with a score > 12 points, need postoperative ventilation.

But this scoring system is not universally applicable for all patients.

2) Preoperative Assessment of Associated Autoimmune Diseases etc.**3) Preoperative Investigations.**

Routine + s. electrolytes (e.g. hypokalemia potentiates myasthenia gravis).

+ AB gases and pulmonary function tests.

4) Preoperative Treatment of myasthenia gravis as above.....

N.B.; The use of anticholinesterases is **controversial** because they produce;

- * **Increased vagal effects** which
 - Increases bronchial secretions and bronchospasm.
 - Induces bradycardia.
 - Increases peristaltic movement.

* **Inhibition of plasma cholinesterase** enzymes prolongs the action of the ester type of local anesthetics, succinylcholine and mivacurium.

Conversely, patients with a severe form of the disease may **deteriorate more on stopping anti-cholinesterases.**

- So, it is recommended that for;

* Patients with a **severe form** of the disease and dependent on anti-cholinesterase, **only decrease the dose preoperatively.**

* Patients with a **mild form** of the disease and dependent on anti-cholinesterase, **stop the drug, even if 4 hours preoperatively.**

5) Premedications:

1- Sedatives: Decrease the dose as there is increased sensitivity to respiratory depressant drugs.

2- Aspiration prophylaxis: as antacids, H₂ blockers, and metoclopramide.

3- Antisialagogue: Atropine i.m. 1 hour before the surgery.

4- Steroid cover: if the patient was on steroid therapy.

Intraoperative Management:**Monitoring:** Standard +

- Invasive ABP (and AB gases): if there is a possibility of intra-thoracic procedures or postoperative ventilation.
- Peripheral nerve stimulator: to adjust the dose of muscle relaxants.

ANESTHESIA WITH NEUROMUSCULAR DISEASES**Choice of Anesthesia:****a) Regional or Local Anesthesia:**

- It is preferred, but with the following precautions;

1- Decrease the dose of local anesthetics:

Due to * Their neuromuscular blocking actions.

* Prolonged action of **ester LAs** due to inhibition of plasma cholinesterases by anticholinesterase therapy.

2- Avoid high level blocks as they may cause hypoventilation.

- Advantages: * Avoids the use of muscle relaxants.

* Avoids loss of consciousness so, decreases the risk of aspiration.

b) General Anesthesia:

As a rule, • Avoid the use of muscle relaxants as much as possible as they may cause an unpredictable response.

• If muscle relaxants are mandatory, use short acting muscle relaxants in the smallest dose possible with a nerve stimulator.

Induction: Thiopentone or ketamine i.v. (**no opioids are used**).

Decrease the dose as much as possible because they cause marked respiratory depression.

Intubation:

By: - **Deep volatile anesthesia** as it produces sufficient muscle relaxation for intubation.

- Succinylcholine (decrease the dose or better avoid it) because;

• It causes an unpredictable response.

• Patients treated with anti-cholinesterase may show prolonged response to succinylcholine because anti-cholinesterases may also inhibit plasma cholinesterases.

Maintenance:

$O_2 + N_2O + \text{Volatile agent-based anesthesia}$

• **Deep volatile anesthesia** allows good muscle relaxation. This decreases the dose or eliminates the need for intraoperative muscle relaxants, because myasthenia gravis patients are very sensitive to the relaxant effects of volatile agents.

• **Avoid non-depolarizing muscle relaxants (even in defasciculation doses),**

Because the decreased Ach receptors up to 70% causes a very sensitive response. If muscle relaxants are necessary in major surgeries requiring muscle relaxation so;

1- Use a small dose (10 – 20% the normal).

2- Use short and intermediate acting agents e.g. atracurium, vecuronium (N.B.; Mivacurium is not suitable for use because it is metabolized by plasma cholinesterase).

3- A peripheral nerve stimulator is essential.

4- Stop anti-cholinesterases for 4 hours before surgery as they may interfere with the action of the non-depolarizing muscle relaxants.

N.B.; corticosteroids cause resistance to steroidal non-depolarizing muscle relaxants e.g. vecuronium, but have no effect on suxamethonium.

• **Avoid opioids** as they produce marked respiratory depression because myasthenia gravis patients are very sensitive to their respiratory depressant effect.

Recovery:

Extubation occurs after;

1. Assessment of the ventilatory function e.g. patient can create a good -ve inspiratory force (of at least – 20 cm H₂O).

2. Good muscle power has returned, detected by using a nerve stimulator.

Postoperative Management:

1- **Elective postoperative ventilation:** for 24 - 48 hours postoperatively.

2- Chest physiotherapy and tracheal suction.

3- Postoperative analgesia:

* Epidural opioids are more safer.

* Parenteral opioids if used, should be used at the minimal dose possible.

Myasthenic Syndrome (Eaton- Lambert Syndrome)

It is an auto-immune disease due to antibodies against presynaptic Ca^{++} channels.

Differential diagnosis: Myasthenia gravis.

	Myasthenia gravis	Myasthenic syndrome
Muscle weakness	<ul style="list-style-type: none"> - In extraocular muscles, bulbar muscle, neck muscle.....etc - Increased by repeated efforts. - Muscle pain is uncommon. - Reflexes are normal. - More in females. 	<ul style="list-style-type: none"> - In proximal limb muscles. - Decreased by repeated efforts. - Muscle pain is common. - Reflexes are depressed or absent. - More in males.
Coexisting diseases	<ul style="list-style-type: none"> - Thymoma etc. 	<ul style="list-style-type: none"> - Small cell carcinoma of lung.
Response to muscle relaxants	<ul style="list-style-type: none"> - Resistant (or variable response) to suxamethonium. - Sensitive to non-depolarizing muscle relaxants. - Good response to anti-cholinesterases. 	<ul style="list-style-type: none"> - Sensitive to suxamethonium and sensitive to non-depolarizing muscle relaxants. - Poor response to anti-cholinesterases.
Autonomic nervous system abnormality	<ul style="list-style-type: none"> - Not present. 	<ul style="list-style-type: none"> - Present.
Treatment	<ul style="list-style-type: none"> - Anticholinesterases, Steroids, plasma-pheresis, azathioprine, and thymectomy. 	<ul style="list-style-type: none"> Steroids, plasma-pheresis, azathioprine, and 3,4-di-aminopyridine.

Muscular Dystrophies

They are group of disorders characterized by painless degeneration and atrophy of skeletal muscles, with a normal sensory system.

The most common types are;

Duchenne's Muscular Dystrophy and Becker's Muscular Dystrophy:

It is an X- linked recessive disease affecting ♂ * Duchenne: 3-5 years old.

* Becker: adolescent.

Anesthetic Problems: the same for both types except for age.

C/P: (It affects muscles)

- Skeletal muscles: - Proximal weakness causes gait disturbances (waddling gait) and **increased incidence of bone fracture** so, care is taken during positioning.
 - Fatty infiltration of calf muscle (**Pseudo-hypertrophy**).
 - **Malignant hyperthermia** may occur so, dantrolene should be available.
- Respiratory muscles: There is degeneration of the muscles which interferes with cough and causes **retention of secretions**, repeated **chest infections** (a cause of death) and **restrictive lung disease** (kypho-scoliosis).

ANESTHESIA WITH NEUROMUSCULAR DISEASES

- **Cardiac muscles:** - There is degeneration of the muscle causing **congestive cardiomyopathy** (a cause of death).
 - Papillary muscle dysfunction causing **mitral regurgitation**
 - **ECG changes** (a tall R wave in V_1 and deep Q wave in limb leads, with a short PR interval, and increased HR).

Volatile agents can cause marked cardiac depression so; opioids are better used.

- **GIT muscles:** Decreased motility is present which increases the **risk of aspiration**.

Anesthetic Techniques:

- **Regional anesthesia is preferred.**
- **Avoid succinylcholine** due to
 - Unpredictable response.
 - Inducing severe hyperkalemia which causes VF.
 - It may trigger malignant hyperthermia.
- **Avoid non-depolarizing muscle relaxant** due to unpredictable response.

Familial Periodic Paralysis

A sudden attack of transient muscle weakness or paralysis lasting hours or days (Sparing respiratory muscles) occurs.

Anesthetic Problems: It is of three types; hypo-, normo- or hyperkalemic.

	Hypokalemic type (Voltage-gated Ca^{++} Channelopathy)	Hyperkalemic type (Na^+ Channelopathy)
- Incidence	• Common.	• Rare
- S. K^+	• < 3.0 mEq/L during the C/P. Repeated s. K^+ monitoring is needed.	• > 5.5 mEq/L during the C/P. Repeated s. K^+ monitoring is needed.
- Avoid	• Glucose solutions (and large carbohydrate diets) as they increase K^+ uptake by cells inducing paralysis.	• K^+ containing solutions.
- Give	• K^+ losing diuretics (mannitol is used instead if diuretics are needed).	• K^+ releasing drugs e.g. succinylcholine.
	• KCl i.v. slowly with ECG monitoring for preoperative treatment.	• Glucose infusion for preoperative treatment.
		• K^+ losing diuretics.
		• Ca^{++} i.v. for hyperkalemia.

- In the 3 types:

Muscle relaxants are used cautiously as they may cause an unpredictable response.

Myotonia (= Increased muscle tone)

- **There are sustained contractions** of muscles after voluntary or mechanical stimulation, which **fail to relax** after the use of
 - Non-depolarizing muscle relaxants.

- General anesthesia.
- Regional anesthesia.

They can **relax** after the use of **local anesthetics injection in contracting muscles**, due to **abnormal Ca^{++} metabolism** as the cellular ATP systems **fails to return Ca^{++} in to the sarcoplasmic reticulum**.

Types:1) Myotonic Muscular Dystrophy:

- It is autosomal dominant, affecting ♂ and ♀ (20-30 years old).

Anesthetic Problems: (and C/P):

- Skeletal muscles: - Muscle spasm is evoked by succinylcholine (and anti-cholinesterases).

So, they are avoided because;

- **They prevent mouth opening for intubation.**
- **Difficult ventilation** due to respiratory, chest wall, and laryngeal muscle spasm.
 - **Distal muscles** are more involved than proximal muscles (unlike most other myopathies).
 - **Postoperative shivering** (associated with volatile agents) can induce myotonic contractions in the recovery room, so avoid shivering by a **small dose of pethidine**.
- **Respiratory muscles:** - There is a decrease in the vital capacity so, take care with barbiturates, opioids, and benzodiazepines, as they increase the respiratory depression.
 - Chronic hypoxia resulting in cor pulmonale.
 - **Hyper-somnolence** with sleep apnea.
 - **Elective postoperative mechanical ventilation** may be needed.
- **Cardiac muscle:** Heart block, arrhythmias, cardiomyopathy, and CHF.
So, **avoid** cardiac depression caused by **volatile agents**.
- **GIT muscles:** Decreased motility increases **pulmonary aspiration**.
So, prophylaxis against aspiration should be taken.
- **Uterine muscle:** **Atony** with prolonged labor.
So, **increased uterine bleeding** may occur.
- **Facial muscles:** Weakness resulting in expressionless facies, ptosis, and dysarthria.
- **Others:** - Endocrine: **Insufficiency of pancreatic, adrenal, thyroid, and gonadal functions**, which need to be assessed and managed.
 - Mental retardation.
 - Cataract.
 - Premature frontal baldness.

Avoid non-depolarizing muscle relaxants because;

- There is an increased sensitivity to them.
- Reversal by anticholinestrases (neostigmine) can evoke muscle spasm by facilitating depolarization of the NMJ.

2) Myotonia Congenita:

- It is autosomal dominant (Thomson's disease) or autosomal recessive (Backer's diseases) appearing early in life.
- It affects **skeletal muscles** only, where muscle stiffness resolves with exercise.

3) Para-Myotonia Congenita:

- It is the same as myotonia congenita except muscle weakness occurs **after exposure to cold** (+ increased s. K^+). So, avoid decreasing ambient room temperature.

Neuromuscular Disorders

They are classified into;

1) Denervation Disorders:

a- Defects in the motor neuron (motor nuclei, tracts, and anterior horn cells):

- 1- Traumatic e.g. spinal cord trauma.
- 2- Diseases e.g. quadriplegia, hemiplegia, poliomyelitis, multiple sclerosis, Syringomyelia, and amyotrophic lateral sclerosis.
- 3- Pharmacologic e.g. anticonvulsant therapy.

Denervation may result in decreased Ach release, with a subsequent up regulation of the endplate receptors, resulting in resistance to non-depolarizing muscle relaxants and excessive K^+ release to depolarizing relaxants.

ANESTHESIA WITH NEUROMUSCULAR DISEASES

b- Defects in peripheral nerves:

- 1- Neuropathy in porphyria.
- 2- Neurofibromatosis.

II) Neuro-muscular Transmission Disorders:

- 1- Myasthenia Gravis.
- 2- Myasthenic syndrome.
- 3- Psuedo-cholineesterase deficiency or abnormalities.

III) Muscular Disorders:

- 1- Myotonia.
- 2- Muscular Dystrophy.
- 3- Malignant hyperthermia.
- 4- Others as • Familial periodic paralysis.
 - Endocrine myopathies as Thyrotoxicosis, Myxedema, and DM.

IV) ICU Neuro-muscular Disorders:

- 1- Polyneuropathy due to sepsis and multiple organ dysfunction syndrome.
- 2- Neuro-muscular effects of acid base and electrolytes imbalance, and hypothermia.
- 3- Myopathy due to prolonged steroid therapy and non-depolarizing blockade.

CHAPTER 24

ANESTHESIA FOR PLASTIC SURGERY

Cranio-Facial Reconstruction and Ortho-Gnathic Surgery

Orthognathic surgery is needed for;

- Dental surgeries e.g. Le Fort osteotomies and mandibular osteotomies.
- Mal-occlusion.

Anesthetic Management:

Anesthetic Problems:

1- Airway management: pre -, intra -, and postoperative.

- **ABC resuscitation protocol** in case of trauma.
- Especially for jaw opening, mask fitting, neck mobility, micrognathia, retrognathia, maxillary protrusion, macroglossia, dental pathology, and nasal patency.
- **The degree of airway obstruction** e.g. aspirated teeth, oral bleeding should be assessed especially in maxillo-facial trauma. So, 1st ensure patency of the airway during patient resuscitation by holding the tongue, lateral head position, good suctioning ... etc.

2- Preoperative Assessment of Other Injuries (in case of trauma).

3- Risk of aspiration (in case of trauma).

4- Induction and Intubation:

A) **Awake intubation** by fiberoptic bronchoscopy in **cooperative** patients may be done.

- **Oral:** It is usually preferred especially in case of face trauma.
- **Nasal:** It may be done.
- Even tracheostomy under LA can be done.

B) **Inhalational induction** in **uncooperative** patients may be done.

A) or B), if there is a risk of difficult intubation.

+ Complete range of equipment should be available.

C) **Rapid sequence induction** if there is a risk of **aspiration**.

- ETT should be a reinforced **armored tube** and efficiently secured in place and to the anesthetic circuit connections.
- A posterior **oro-pharyngeal pack** is inserted after intubation and induction to prevent blood and debris reaching the larynx. There should be a mark indicating its presence and it should be removed before extubation.

5- Increased blood loss:

So, * 2 large bore i.v. cannulas are placed.

- * Cross-matched blood units are prepared.
- * A slight head up position is maintained.
- * Local infiltration with epinephrine is advised.
- * Invasive BP (because surgeons may lean against the patient's arm interfering with the non-invasive ABP cuff reading).
- * Controlled hypotension anesthesia is used.

ANESTHESIA FOR PLASTIC SURGERY**6- Postoperative Management:**

1. Postoperative edema of the airway e.g. tongue or larynx so, leave the patient intubated.
2. If the jaws are wired and fixed in full occlusion so, a pair of **wire cutters** must be kept always by the patient's **bedside** to release the jaw fixation if vomiting occurs.

N.B.; Cleft lip and cleft palate: "see pediatric anesthesia later".

Limb Surgery

- It is usually limb reimplantation by micro-surgical reanastomosis of vessels and nerves. The patient is young and healthy with a traumatic limb, hand or finger amputation.

Anesthetic Problems:

- 1- **Local and regional anesthesia** are preferred, but there are 2 disadvantages:
 - **Bier's block** is of **limited value** as the **surgeon** often requires **cuff deflation** to **identify the bleeding points**.
 - **The duration** of some surgeries may **exceed the LA technique** duration so, an **epidural catheter** is preferred.
- 2- **Prolonged GA** (up to 12 – 24 hours) requires the following precautions:
 - Maintain body **temperature** (avoid hypothermia).
 - Maintain accurate **fluid balance** (avoid hypovolemia).
 - Measures to **protect pressure areas** by a ripple mattress.
 - Measures **against DVT**.
 - **Arterial cannula** for invasive **ABP** and **AB** gases to ensure **normocapnia**.
 - The use of **humidified gases** in warm operation rooms.
 - The use of **isoflurane or sevoflurane** is of choice.

Due to: - Little biotransformation.

- Rapidly elimination.

- They induce VD in normo-volemic patients, which is beneficial to the outcome of surgery.

• **Avoid N₂O** as on prolonged exposure, it causes bone marrow depression and.....etc.

Q: What is the anesthetic management in lengthy operations?

- 3- **Avoid vascular spasm** in the limb by preoperative **i.v. sympathetic blockade** using
 - Guanethidine 15 – 20 mg.
 - Heparin 500 units.
 - Prilocaine 0.5%.
- 4- Postoperatively, maintain **good arterial blood flow after the re-anastomosis**. This depends on:
 - **Hypothermia**: It should be avoided by:
 - Forced-air warming blankets, i.v fluid warmers,.....
 - **Hypovolemia**: It should be avoided by:
 - Monitoring of UOP, CVP, and blood loss.
 - A mild degree of anemia can increase the blood flow by altering blood rheology i.e. decreased viscosity.
 - **Dextran 40** improves microcirculatory blood flow by decreasing the viscosity and inhibiting the platelet function.
 - **Continuous regional nerve blocks** may cause sympathectomy so, VD occurs which increases the regional blood flow.

Burns

Classification of Burns:

a) According to the Surface Area (Rule of Nine):

- It expresses the extent of the burn injury as a percentage of the total body surface area (TBSA) displaying either 2nd or 3rd degree burns (figure 24-1).

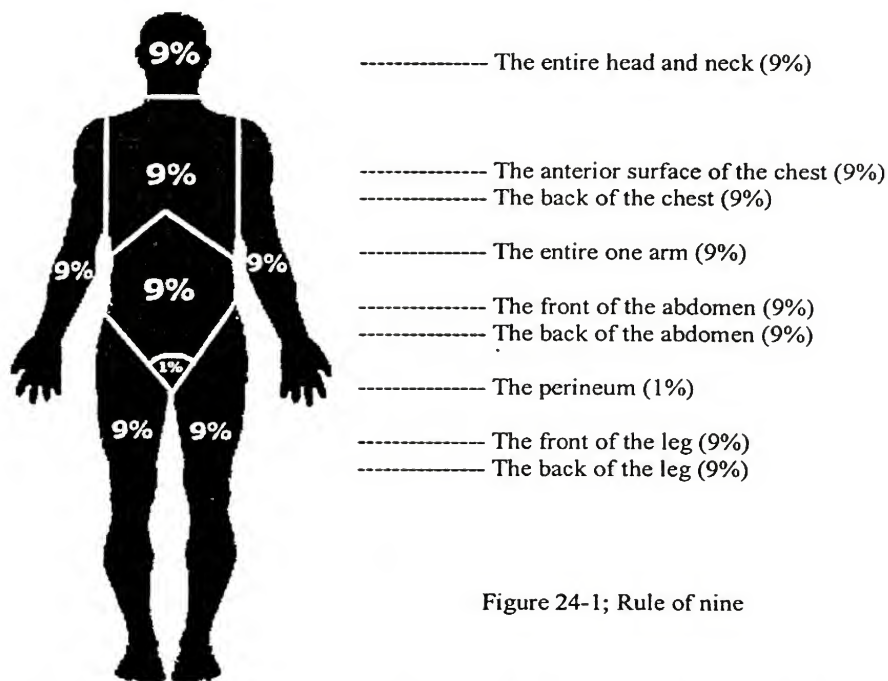


Figure 24-1; Rule of nine

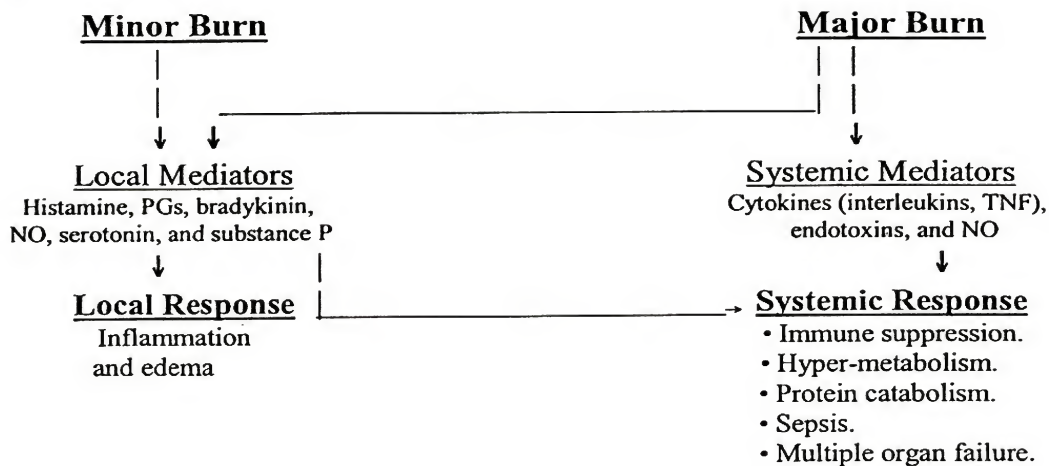
- In children, this rule should be modified because the head and neck are proportionately larger than in adults so, age-adjusted nomograms (e.g. tables of Lund and Browder) can be used (rule of ten).

b) According to the Depth:

- **1st Degree (Superficial) Burn:** It affects the **epidermis** only.
- **2nd Degree (Partial Thickness) Burn:** It affects the **epidermis + dermis** causing bullae and blisters, but it can spontaneously heal by the epithelium around hair follicles (it is the most painful).
- **3rd Degree (Full Thickness) Burn:** It affects the **epidermis + dermis + dermal appendages** (i.e. all skin thickness). It needs a skin graft for healing.
- **4th Degree:** It affects **all the skin, bony tendons, and muscle**. It is treated by debridement and even amputation.

Definition of Major Burns: (According to the American Burn Association)

- Full-thickness burns > 10% TBSA.
- Partial-thickness burns > 25% in adults or 20% in extremes of age.
- Burns involving the face, hands, feet, or perineum.
- Inhalational, chemical or electrical burns.
- Burns in patients with serious preexisting medical disorders.

Effects of Burn:**1) Pulmonary Effects:****1- Inhalational Injuries:**

- C/P: During the 1st 24 hours post-burn, usually no signs or symptoms occur (i.e. clear or lucid interval).

Then, stridor, hoarseness, facial burn, singed nasal hair, or eyebrow, soot in the sputum or in the oropharynx, respiratory distress or history of combustion in a closed space are present. Those are indications of inhalational injury and need further airway assessment by a fiberoptic bronchoscopy.

- Effects of inhalational injuries: **hypoxemia** by:

• Direct Thermal Injury to the Airway: It causes mucosal and ciliary damage resulting in airway edema and then airway obstruction (this needs early intubation even if only suspicious).

• Effect of Smoke (Air-Born) Toxins Inhalation:

- **Water soluble gases** from burning plastic or rubber as **ammonia, sulfur dioxide, and chlorine** react with water in mucous membranes producing strong acids and alkali. This causes bronchospasm, mucous membrane ulceration, corrosion, and airway edema.

- **Lipid soluble gases** as **phosgen** are transported to the lower airways on carbon particles that adhere to the mucosa causing damage of cell membranes and edema.

- **Hydrogen cyanide** (released from synthetic materials) further limits O₂ availability and utilization causing cyanide toxicity.

• Decreased Inspired O₂ Concentration in a Smoke-Filled Atmosphere resulting in Asphyxia which is the main cause of death in the acute stage.

• Deactivation of Surfactant, Epithelial Destruction, and Increased Capillary Permeability: All cause pulmonary edema and acute respiratory distress syndrome.

2- Carbon Monoxide Poisoning: It causes hypoxemia.

- It has a greater affinity (200 times more) for Hb than O₂, so it displaces O₂ from its Hb binding sites.

- It shifts the O₂-Hb dissociation curve to the left interfering with the unloading of O₂ at tissues.

So; O₂ administration is important as the half life of carbon monoxide can be decreased from 4 hours to 45 minutes with 100% O₂ (hyperbaric O₂ can be used in the treatment).

3- Circumferential Burns of the Thorax:

- They decrease chest wall compliance, so increase the peak airway pressure resulting in hypoxemia.

4- During the Healing Phase of Burns:

- There is increased metabolism i.e. a **hyper-metabolic state** which increases O₂ consumption and CO₂ production. This can continue for weeks or months until healing occurs.

Q: What are the causes of hypoxemia in a burned patient?

2) CVS Effects (Fluid Imbalance):**a) Acute Phase (during the first 24 – 36 hours):**

There is a large amount of **protein-rich fluid lost** from the burned wound site (due to direct thermal destruction of the capillary membrane) and from the micro-vascular circulation throughout the body into the interstitial fluid. This decreases the **blood volume** (i.e. a **burn shock is produced**) leading to;

- **Hemoconcentration.**
- **Increased ADH secretion** so the UOP decreases or even stops.
- **Decreased cardiac output (50%)** due to:
 - Decreased blood volume (i.e. decreased preload).
 - Increased circulating CAs which causes VC (i.e. increased afterload).
 - A myocardial depressant protein which decreases the contractility.

These decrease tissue perfusion which;

- Further decreases the UOP.
- Decreases hepatic functions, so s. albumin is decreased and the detoxifying effect of the liver is decreased resulting in increased free drugs as benzodiazepines and phenytoin.

N.B.; S. α_1 acid glycoprotein is increased during the acute phase resulting in an increase in the binding of basic drugs e.g. muscle relaxants, lidocaine and propranolol.

- **Edema all over the body including pulmonary edema.**

b) Subacute Phase (after the first 24 – 36 hours):

- **Capillary integrity returns to normal** so, **colloids remain intravascular**, increasing the intravascular oncotic pressure which increases the interstitial fluid reabsorption. This increases the intravascular volume which, besides the increase in the circulating CAs and hyper-metabolic state, produces a **hyper-dynamic circulation** with **high CO failure** (i.e. increased ABP and HR).

3) Electrolyte Imbalance:

1- Hyperkalemia: especially during the acute resuscitation phase.

- Due to:
 - Tissue destruction.
 - RBCs hemolysis (so, anemia occurs late in recovery).
 - Acidosis caused by infection.
- Then **hypokalemia** occurs, due to renal wasting and gastric loss.

2- Hemoconcentration (Relative Hypernatremia):

- Due to:
 - Increased aldosterone release induced by hypovolemia which increases Na⁺ reabsorption.
 - Increased ADH release by hypovolemia which decreases the UOP.

3- Topical Antibiotics:

- e.g.:
 - Mafenide acetate: It inhibits carbonic anhydrase enzyme causing hyperchloremic acidosis.
 - Silver nitrate: It decreases s. Na⁺, Cl⁻, and K⁺ (+ it produces met-hemoglobinemia).

ANESTHESIA FOR PLASTIC SURGERY**4) Infection and Septic Shock:**

- It is the major cause of morbidity and mortality in burn patients who survive the initial insult.
- Because:
 - Burned skin and eschar are a perfect culture medium.
 - Loss of skin provides an easy route of entry of micro-organisms.
- So;
 - **Strict antiseptic precautions** must be applied in handling these patients to decrease the risk of cross contamination between patients.
 - **Quantitative wound biopsies** are obtained to do culture and sensitivity.
 - **Change catheters** which are cultured routinely every 3 days.

5) Hematologic System Effects:

- Infection and burns cause;
 - Subacute activation of the coagulation cascade causing consumption of circulating procoagulants. This produces various degrees of **coagulopathy up to DIC**.
 - Decreased **platelet** number and function.
 - Decreased **RBCs** survival so, a peripheral blood smear shows many fragmented and deformed RBCs.

6) Stress (Curling's) Ulcer:

- It occurs in 86% of cases especially a duodenal ulcer so, **prophylactic antacids and H₂ blockers** are used.

7) Thermoregulation Alteration:

- There is resetting of the centrally mediated thermostat, so normothermia for a burned patient is about 38.5°C.

8) Other Effects of Electrical Burns:

- The burn occurs from the conversion of high-voltage electrical energy to thermal energy leading to;
 - **Skin burns** at the site of entrance and exit.
 - **Extremities are vulnerable**, due to the decreased volume for diffusion of the current (in contrast to a large viscera which is often spared due to its large volume which permits dissipation of the thermal insult).
 - Damage of vascular epithelium resulting in **delayed thrombi** formation.
 - **Muscle damage** causes release of myoglobin into the blood (**myoglobinemia**) which in turn causes **acute RF** (It needs aggressive volume expansion and diuresis especially mannitol).
 - **Heart damage** causes;
 - Increased s. creatine phosphokinase CPK-MB isoenzyme (Myocardial infarction).
 - Ectopy and arrhythmias.
 - CHF.

Resuscitation of a Burned Patient:**ABC protocol****1) Airway:**

- Bronchial suction and removal of debris.
- Even intubation.

2) Breathing:

Adequate ventilation is maintained by IPPV + humidification with 100 % inspired O₂ ± PEEP.

3) Circulation:

- It is maintained by fluid correction especially in **the first 24 hours** to ensure vital organ perfusion e.g. avoiding acute RF by maintaining the UOP at > 1 mL/Kg/hr.

- Many formulas have been postulated:

a) Parkland (Baxter) Formula: (it is the most common).

• **In the 1st 24 hours:**

- Type: **Isotonic crystalloid** solutions e.g. **lactated ringer, or normal saline** (no colloids).

- Dose: **4 mL / Kg / % of the burned area** with 2nd and 3rd degree burns.

- Rate: $\frac{1}{2}$ the amount given in the 1st 8 hours.

$\frac{1}{4}$ the amount given in the 2nd 8 hours.

$\frac{1}{4}$ the amount given in the 3rd 8 hours.

- UOP should be maintained at 0.5-1 mL/Kg/hour.

• **In the 2nd 24 hours: (after the 1st day)**

- Types: • **D₅W** in adults + 25%-50% of the amount in the form of **NS** in **children** to avoid hyponatremia and maintain s. Na⁺ at 140 mEq/L.

• **Colloids** e.g. human albumin or fresh frozen plasma (avoid colloids in the 1st day as they will be extravasated into the interstitial tissues).

- The dose of colloids: according to the % of the burned area.

When the burned area is 30 – 50%, give 0.3 mL/Kg/% of the burned area.

When the burned area is 50 – 70%, give 0.4 mL/Kg/% of the burned area.

When the burned area is > 70 %, give 0.5 mL/Kg/% of burned area.

- UOP should be maintained at 0.5-1 mL/Kg/hour.

b) Muir and Barclay Formula:

- It is used in cases of > 15% burn in adults or > 10% burn in children.

- Type: • 50% as **crystalloids** + 50% at least as **colloid** (human albumin).

• If extensive full thickness burns are present, some of the above fluids are given as **whole blood**.

- Dose: **Body weight (in Kg) × % of the burn** gives the amount in mL, in each of the following **six periods**, from the time of burning.

0 – 4 hrs → 4 – 8 hrs → 8 – 12 hrs

12 – 18 hrs → 18 – 24 hrs → 24 – 36 hrs.

4) After Initial Resuscitation:

• The burned patient is **monitored** closely for several days.

• **Control of infection** is continued by;

- Systemic antibiotics.

- Topical antibiotics e.g. silver sulfadiazine (it has no effect on electrolytes, but on prolonged use, neutropenia and development of resistant organisms may occur).

N.B.; Side effects of silver nitrate and mafenide acetatesee above.

5) Excision of Dead Eschar (the Area with a Full Thickness Burn) and Grafting.

Anesthetic Management:

Preoperative Management:

After resuscitation and burn assessment; preoperative assessment of different systems is needed to detect the complication of burn.

Premedications:

- Sedatives: They are avoided in critically ill patients with hemodynamic instability.

- Antibiotics.

Intraoperative Management:

Monitoring: Standard + according to the patient's condition as; ECG, arterial line for invasive ABP and AB gases, CVP, PCWP, UOP, and peripheral nerve stimulator.

Induction and Intubation:

- Great care should be taken especially in case of burns of the head and neck.

ANESTHESIA FOR PLASTIC SURGERY

a) **Awake intubation** in cooperative patients by a fiberoptic bronchoscope.

- Oral.

Or - Nasal: especially if prolonged postoperative intubation is planned because:

- It is easily secured in place.
- It is better tolerated by the patient.
- It allows oral hygienic care.

b) **Inhalational induction** in uncooperative patients with suspected difficult intubation.

Problems During Intubation:

- **The range of movement in the neck and temporo-mandibular joint** may be grossly restricted so, laryngoscopic intubation may be impossible.
- **The raw painful tissues** may prevent application of the face mask.
- **Tracheostomy is undesirable** due to the increased risk of spread of infection to the damaged skin.
- **Suxamethonium is avoided** in burned patients with muscle damage;
 - Because suxamethonium may increase the release of K^+ into the circulation reaching very dangerous levels (10 mEq/L has been reported). This may cause cardiac arrest due to presence of **extra-junctional Ach receptors** that increase the sensitivity of the muscle membrane.
 - The period of increased sensitivity (and so, avoidance of suxamethonium) is unclear. It differs from centers to others.
 - Some avoid suxamethonium from the 1st 24 – 48 hours up to healing with a maximum limit of 2 years.
 - Others avoid suxamethonium from the 4th day up to 10 weeks only after thermal injury.
 - This effect is present **irrespective of the degree or the extent of burn** as it can occur in patients even with < 10% burns.

• **There is a difficulty in securing the E.T.T in place;**

So either: - Suspend the anesthetic breathing system from the ceiling.

- Use an umbilical tape to tie the tube in place.

Or - Wire the tube to the upper teeth.

Maintenance: According to the patient's hemodynamics:

$O_2 + N_2O +$ **high dose opioid (during the acute phase)** or **volatile agents (during the subacute phase)** + muscle relaxants + special CMV.

- Opioids: They produce less myocardial depression so, they are best used in the acute phase.

- Volatiles: They can be used after the acute phase only because;

- They produce marked myocardial depression.
- They increase arrhythmias especially if halothane is used with epinephrine-soaked bandages which are used to decrease bleeding.

- Ketamine infusions: can be used during burn dressing with special care for;

- Maintaining airway.
- Giving anti-sialagogue.
- Giving diazepam to decrease hallucinations.

- Muscle relaxants: Increase the dose of non-depolarizing muscle relaxants due to;

- Increased α_1 glycoprotein which increases plasma protein binding of muscle relaxants.
- Increased number of extra-junctional Ach receptors which bind muscle relaxants without causing a block.

- Mechanical ventilation:

- It is essential in severely burned patients due to (causes of hypoxia).

• **Special ventilators** are needed that can provide high minute volumes (up to 30 L/min), high peak pressure, and PEEP e.g. MA – 2, Siemens servo or PB 7200.

Intraoperative Problems:

1) Increased Blood Loss:

- Especially if the surgery is done for:
 - A graft within more than a few days after the burn.
 - Areas which cannot be isolated by a tourniquet.

2) Hypothermia:

- Due to:
 - Evaporation from the burned area.
 - Inability to constrict cut vessels and so, inability to decrease heat radiation.
 - Effects of GA on the heat regulating center.
- Methods to decrease heat loss:
 - Blood warmers to warm blood and i.v. fluids.
 - Warming blanket.
 - Covering of body areas not involved in the surgery.
 - Gas humidification by a heated-humidified circuit.
 - Ambient theater temperature at (27°C) and humidity of (50%).

Extubation:

- **Awake extubation.**
- Before extubation, examine the larynx and pharynx because **edema** may be present around the base of the tongue producing respiratory obstruction after extubation.

Postoperative Management:

- 1- Care during patient's transport with standard monitors.
- 2- Postoperative ventilation is needed in case of severe pulmonary affection.
- 3- Postoperative analgesia especially at sites of skin graft donor.
- 4- **Postoperative psychologic support** may be needed for patients who have been grossly deformed or with an amputated limb.

CHAPTER 25

ANESTHESIA WITH NUTRITIONAL DISEASES

Obesity

Definitions:

- **Overweight:** Excess body weight $\geq 20\%$ than the ideal body weight (some authors consider overweight, an early stage before obesity).
- **Obesity:** Excess adipose tissues $\geq 20\%$ than the ideal body weight.
- **Morbid Obesity:** Body weight is more than twice the ideal body weight.
- **Body Mass Index (BMI) or Quetelet's Index:**

$$= \frac{\text{Body weight (Kg)}}{\text{Height square (m}^2\text{)}}$$

Values of the BMI:

Degree of the obesity	BMI (Kg/m ²)
- Normal individuals	20-25 (some authors say, males 22 and females 20)
- Overweight	25-30
- Obesity (BMI is increased 30% above the normal)	30-40
- Morbid Obesity	> 40

N.B.; A triceps skin-fold thickness of more than 23 mm in men and more than 30 mm in women is defined as obesity.

Distribution of Fat:

- **Central obesity:** fat is mainly around the upper abdomen and viscera (waist), this type is the most risky type for medical conditions.
- **Peripheral obesity:** fat is mainly around the gluteofemoral and lower abdomen regions, this type has little or no risk on the medical condition.

So, the **Waist Circumference** is used nowadays to indicate the presence of central obesity. It is for males > 102 cm and for females > 88 cm

N.B.; **Ideal body weight** can be detected by:

- Actuarial tables depending on height, sex, and body frame size.
- Broca index (used practically) = Height in cm – 100 for males.
– 105 for females.

Clinical Manifestations (Anesthetic Problems):

There is an increased metabolic rate and a large sized body.

1) Respiratory System:

- 1- **Picture of Restrictive Lung Disease:** i.e. there is decrease in IRV, ERV, FRC, VC, and TLC due to decreased chest wall compliance by excessive adipose tissues over the thorax.
- 2- **Ventilation/Perfusion Mismatching** (i.e. increased intra-pulmonary shunt) due to;
 - **Decreased ventilation** caused by a decrease in the FRC below the closing capacity because the lung is compressed from the external adipose tissues (the closing capacity is not

changed or increased), so some alveoli will close during normal tidal volumes. This is avoided by PEEP and increased FiO_2 .

- **Increased perfusion** caused by an increase in the CO and blood volume.

Both decrease the V/P ratio.

3- V_D/V_T is often **less than the normal** due to the increased tidal volume and the unchanged dead space.

Bohr equation = $\text{V}_D/\text{V}_T = (\text{PaCO}_2 - \text{PÉCO}_2)/\text{PaCO}_2$

PÉCO_2 = Mixed expired CO_2 tension.

4- **Obesity – Hypoventilation Syndrome (Pickwickian Syndrome):**

- It occurs in **extremely obese patients** (8% of all obese patients).
 - It causes;
 - Hypoventilation resulting in **hypoxemia and hypercarbia**.
 - Cyanosis induced **polycythemia**.
 - **Right sided heart failure with pulmonary hypertension**.
 - **Obstructive sleep apnea** as once sleep begins, upper airway obstruction occurs by a large tongue or uvula (where adipose tissues deposit in the lateral pharyngeal wall which is not fixed to the bone and highly mobile. So, they protrude into the airway during -ve airway pressure i.e. during inspiration) or it may be a central effect. This causes heavy snoring, hypoxemia, and hypercarbia. Therefore, arousal (nocturnal awakening) with return of normal respiration occurs. In chronic conditions, sleep deprivation occurs leading to daytime somnolence.
 - Postoperative ventilation is usually needed after abdominal surgery.
- N.B.; Pickwickian syndrome was named by **Burwell in 1956** as he felt that the first adequate description of this syndrome had been made in 1837 by **Charles Dickens** in the posthumous papers of the **Pickwick club** in which he describes a boy with the same feature of this syndrome.
- So, AB gases are essential.
- In most young active obese patients, hypoxemia with normal PaCO_2 occurs.
 - In **pickwickian syndrome**, **hypoxemia with increased PaCO_2** occurs.

2) CVS:

1. There is **increased CO** due to an increase in the SV and a greater increase in the HR. This increases the work of the heart.
Also, there is **increased blood volume** (2ry to polycythemia).
Both increase the ABP and CHF.
2. There are **conduction defects** due to fatty infiltration of the conduction system.
3. There is an increased incidence of **coronary artery disease and atherosclerosis**.
4. In **Pickwickian syndrome**, there is **pulmonary hypertension and cor pulmonale (RVF)** due to - Increased pulmonary blood flow.
- Hypoxic pulmonary vasoconstriction.
- 5- There is an **increased** incidence of **DVT** due to;
 - Chronic limited mobility.
 - Polycythemia which increases blood viscosity.
 - Increased abdominal pressure which causes venous stasis.

3) GIT:

- 1- There is an increased incidence of;
 - Hiatus hernia.
 - Gastroesophageal reflux.
 - Poor gastric emptying (it is controversial).
 - Hyper-acidic gastric fluid.

ANESTHESIA WITH NUTRITIONAL DISEASES

All these increase the **risk of regurgitation** and aspiration pneumonia.

2- **Fatty infiltration of the liver** (usually not affecting the liver function).

There is increased biotransformation (reductive pathway) of volatile agents.

3- **Cholelithiasis (gall bladder stones).**

4) Metabolic Effects:

1. There is an **increased metabolic rate** in proportion to the increased body weight resulting in **increased O₂ consumption and CO₂ production**. Both cause hyperventilation.

2. **Type II diabetes mellitus**, hyper-insulinoma and increased insulin resistance.

3. **Hyper-cholesterolemia, hyper-lipidemia, and hyper-triglyceridemia.**

5) Airway Problems:

There is **difficult** airway management (mask ventilation and intubation) due to decreased mandibular and cervical mobility, short neck and large tongue.

6) Other Problems: There is;

- Osteo-arthritis so, care is taken during **positioning**.
- Increased difficulty in **surgical techniques**.
- Increased difficulty in **local anesthetic techniques**.
- Increased difficulty in achieving **venous access**.
- Increased **blood loss**.
- Increased **wound infection and wound dehiscence**.
- Increased **bed sores**.

7) With Pregnancy:

- There is addition of the physiologic changes of pregnancy to the pathologic changes of obesity.
- There is increased incidence of **pre-eclampsia, and aorto-caval compression**.

Anesthetic Management:

Preoperative Management:

1- **Preoperative Assessment** history, examination, and full investigations of the respiratory system, CVS, hematology, GIT, metabolic, airway.....and all are managed.

2- **Premedications:**

Avoid i.m. injections because they usually causes intra-fat injection leading to unpredictable absorption so; only use i.v. injections or the oral route.

N.B.; Avoid i.m. injections in;

- Morbid obese patients.
- Blood diseases e.g. hemophilia.
- Febrile children.

1. Sedatives:

- In non-pickwickian patients, slight sedation is allowed.
- In pickwickian patients, no sedation is allowed.

2. Prophylaxis against aspiration: antacids, H₂ blockers or metoclopramide.

3. Prophylactic antibiotics.

4. Prophylactic anticoagulants.

Intraoperative Management:

Monitoring: Standard + (According to the patient's condition).

- Non-invasive ABP: The **suitable cuff size** should be chosen or use the regular sized cuffs on the forearm.
- Invasive ABP and AB gases.
- CVP and PA catheter.

Choice of Anesthesia:

A) Regional Anesthesia: with the following precautions;

- It is **more difficult** in obese patients to identify landmarks and needs longer needles.
- **Spontaneous ventilation** is difficult to be maintained in the supine position.
- **Decrease the dose** for epidural or subarachnoid block by 20 – 30% less than the ordinary doses due to; - Presence of epidural fat.
- Distended epidural veins due to increased intra-abdominal pressure.

Combined continuous epidural (lumbar, thoracic or cervical) anesthesia with light endotracheal GA is recommended because:

1. They decrease the stress on the CVS during surgery causing more stable hemodynamics (i.e. decreased ABP, HR, and SVR).
2. This method avoids the usage of opioids or potent inhalational agents.
3. There is rapid postoperative emergence causing early extubation.
4. It allows postoperative analgesia without respiratory depression.

B) General Anesthesia:**Induction and Intubation:**

- **Good preoxygenation** is essential with 100% O₂ (to obtain a 99% - 100% SaO₂).
- Because: - Rapid desaturation occurs during periods of apnea in obese patients as there is a small intra-pulmonary store of O₂ (i.e. small FRC) which is rapidly consumed due to the high metabolic rate.
- Difficult intubation is suspected needing a longer time.
- **All equipments** (e.g. LMA or combi-tube) **for difficult intubation** should be available.
- a) **Awake intubation in cooperative patients** is done by fiberoptic bronchoscopy if difficult intubation and aspiration is suspected.
- b) **Inhalational intubation in uncooperative patients** is done if difficult intubation is suspected.
- c) **Rapid sequence induction and intubation** is chosen if easy intubation is suspected, but there is a risk of aspiration.
- Succinylcholine: Increase the dose (1.2-1.5 mg/kg) due to the high pseudo-cholinesterase activity in obese patients.
- There may be **difficulty in auscultating breath sounds** so, **ETCO₂** is essential.

N.B.; Careful Drug Dosing is needed as;

- Drug dosing based on the actual body weight causes over-dosage.
 - Drug dosing based on the ideal body weight is frequently inadequate.
- So, the best dose often lies somewhere in between both.

Increased blood volume dilutes the drug plasma concentration, but adipose tissues are relatively poorly perfused so injected drugs will be distributed primarily to the central circulation.

It is recommended to calculate drug doses on the ideal (lean) body weight.

Patient Position:

- Careful positioning is needed as the patient **may fall down** especially in abnormal positions.
- Very obese patients may need **special O.R tables** (as most OR tables can carry 120 – 150 kg only).

Maintenance:

O₂ + N₂O + volatile agents + muscle relaxants + IPPV

- O₂: It should not be < 40% to avoid hypoxemia especially in the prone, trendelenburg, and lithotomy positions.

- Volatile agents: There is a general increase in hepatic biotransformation (metabolism)

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- **Isoflurane, desflurane, or sevoflurane** are drugs of **choice** because they have very low hepatic biotransformation.
- **Avoid** those with high hepatic biotransformation (reductive pathway due to hepatic hypoxia) as - **Halothane** increases the incidence of halothane hepatitis.
- **Methoxyflurane** increases the incidence of nephro-toxicity (by increased fluoride ions).

N.B.; **Opioids are avoided** because they are lipid soluble drugs so, they are distributed to the large fat mass i.e. they have increased volume of distribution which prolongs their action and increases their respiratory depressant action.

- Muscle relaxants:

All can be used, but;

- **The dosage** should be based on the **ideal (or lean) body weight** rather than on the actual body weight otherwise over-dosage can occur.
- **Peripheral nerve stimulators** should be used to avoid over-dosage.
- Start with the possible smallest dose, then increase the dose according to the patient's need.

- IPPV:

- **Large tidal volumes** are needed to provide better oxygenation and CO₂ elimination and to prevent atelectasis, but they increase the risk of pneumothorax.

Recovery and extubation:

- Early awake extubation is usually done especially in non-pickwickian patients.
- Criteria of extubation include:
 - An awake and alert patient.
 - Complete reversal of muscle relaxants
 - Hemodynamically stable.
 - Acceptable AB gases on 40% O₂
 - pH 7.35 – 7.45
 - PaO₂ > 80 mm Hg.
 - PaCO₂ < 50 mm Hg.
 - Acceptable respiratory mechanics
 - Maximum inspiratory effort < 25 – 30 cm H₂O.
 - Vital capacity > 10 – 15 mL/Kg.
 - Tidal volume > 5 mL/Kg.

Postoperative Management:

1) Postoperative Analgesia:

- Especially for thoracic or abdominal surgeries.
- By • Continuous epidural block (LAs or opioids).

N.B.; Close observation for delayed respiratory depression is essential if opioids are used.

- I.v. opioids in the smallest possible dose.
- Patient controlled analgesia with opioids.

N.B.; Avoid routine i.m. opioids injections.

2) Postoperative Complications:

1- Postoperative Pulmonary Dysfunction: It causes hypoxemia (which lasts 4 – 6 days)

- Especially in - Morbid obese patients.
 - Presence of preoperative hypoxemia.
 - Surgery involving thorax or upper abdomen (especially vertical incisions) leading to inability to cough due to splinting pain.

- So,

- O₂ supplementation is needed by a nasal cannula or mask for 4 – 6 days with CPAP.

- ## Malnutrition

- 1) **Fluid Depletion**: hypovolemia and dehydration occur.
- 2) **Electrolyte Imbalance**: e.g. **hypokalemia** due to repeated vomiting.
- 3) **Hypoproteinemia**: (s. albumin < 2.5 gm/dL) so, human albumin infusions are needed.
- 4) **Vitamins and Minerals Deficiency**:
 - As iron deficiency resulting in **hypochromic anemia**.
Vitamin B₁₂ or folate deficiency resulting in **megaloblastic anemia**.
 - So, multivitamin preparations should be given.
- 5) **Depressed Immune System**: so, there is an increased risk of **infections**.
- 6) **Delayed Wound Healing**: resulting in wound dehiscence.
- 7) **Delayed Gastric Emptying**: increasing the risk of aspiration.
- 8) **Decreased Bone Density and Muscle Strength**.
- 9) **CVS**: Decreased VR causing decreased CO (with decreased HR and ABP).
Due to:
 - Dehydration, hypovolemia, and reduced blood volume.
 - Decreased core temperature.
 - Decreased T₃ level.
- 10) **Total Parenteral Nutrition (TPN)**:
 - It may be given preoperatively or postoperatively.
 - TPN complications see later.

CHAPTER 26

ANESTHESIA WITH BLOOD DISEASES

Blood Physiology

Hemostasis

It occurs in 3 phases.

- 1) Vascular contraction of smooth muscles causes VC due to release of thromboxane A₂ from platelets.
- 2) Formation of a **platelet plug** (1ry hemostasis).
- 3) Formation of a firm clot (**coagulation**).

Formation of a Platelet Plug (1ry Hemostasis)

Mechanism

It is the function of platelets by:

- 1) Platelet adhesion: It is the affinity of platelets to non-platelet surfaces.
 - 2) Release reactions.
 - 3) Platelet aggregation: It is the affinity of platelets to one another.
- Then reinforcement of platelet aggregation occurs with fibrin strands leading to formation of a hemostatic plug.

Values:

Normal platelet count = $150 - 400 \times 10^9 / \text{liter}$.

N.B.; Thrombocytopenia = $< 100 - 150 \times 10^9 / \text{liter}$.

N.B.; $100\,000 / \mu\text{L} = 100 \times 10^9 / \text{liter} = 100\,000 / \text{mm}^3 = 100 \times 10^6 / \text{mL}$.

Formation of a Firm Clot (Coagulation)

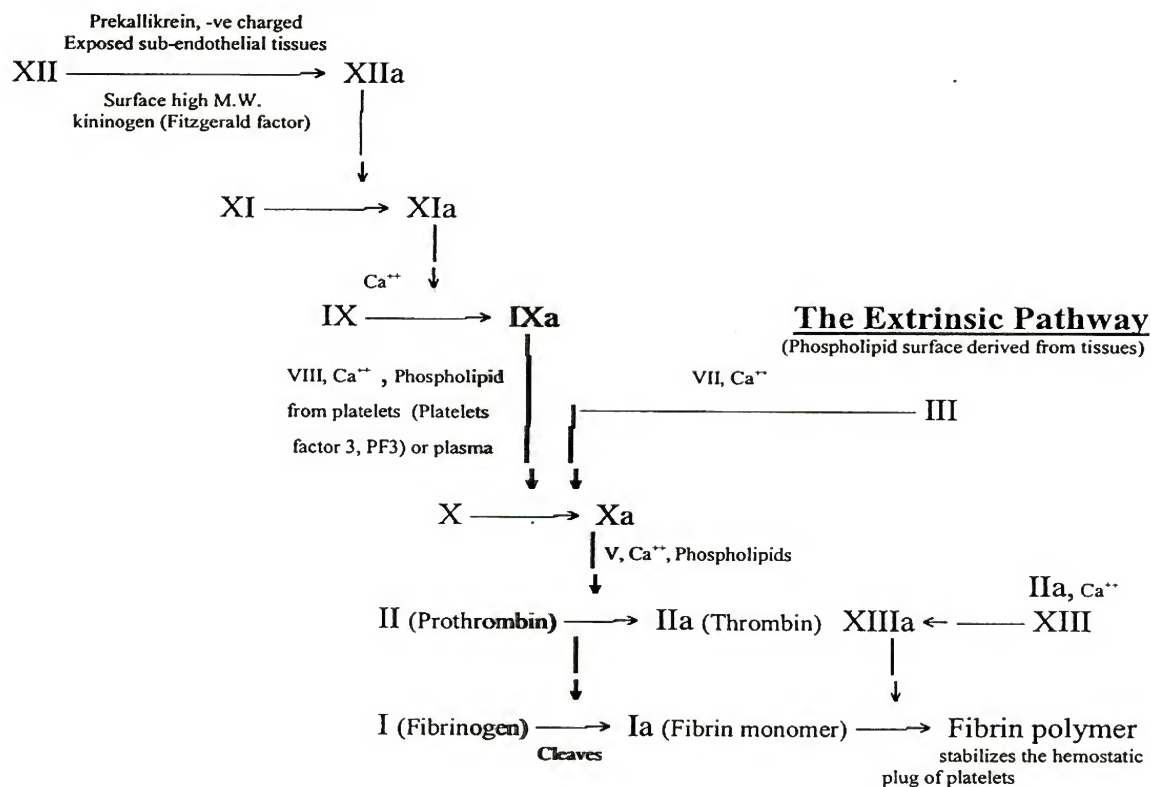
Clotting Factors	Name	Half life (hours)
Factor I	Fibrinogen	100
Factor II	Prothrombin	80
Factor III	Tissue thromboplastin	-
Factor IV	Calcium ions	-
Factor V	Labile factor (proaccelerin)	18
Factor VII	Stable factor (proconvertin)	6
Factor VIII	Anti-hemophilic factor (AHF)	10
Factor IX	Christmas factor	24
Factor X	Stuart-Prower factor	50
Factor XI	Plasma thromboplastin antecedent (PTA)	25
Factor XII	Contact factor, Hegman factor	60
Factor XIII	Fibrin stabilizing factor	90

(There is no factor VI)

N.B.; Labile factors are V and VIII because their coagulant activity does not last long in stored blood so, packed RBCs are deficient in these factors.

The Intrinsic Pathway

(i.e. all components circulate in plasma)



N.B.; Serine Proteases are thrombin and plasmin.

Anti-thrombin III is a naturally occurring **protease** inhibitor. It inhibits thrombin and other serine proteases.

The Coagulation Screen

Indication:

a) Elective:

1. With a **suspicious history** (bleeding after a wound, previous surgery or easy bruising, suspected DIC).
2. With **massive blood transfusion**.
3. With a **family history** due to **inherited** disorders.
4. **Patient receiving anticoagulants** as warfarin, heparin, aspirin... etc.
5. With inter-current illness as **obstructive jaundice**, liver disease, uremia.....

b) Emergency or Intraoperative:

With **excessive bleeding** despite **apparent vascular integrity**.

Normal Values:

Test	Normal value	Comment
Prothrombin time (PT)	12-14 sec	It tests the extrinsic (III and VII) and common pathways (I, II, V, and X).
Partial thromboplastin time (PTT)	35 – 45 sec	It tests the intrinsic (VIII, IX, XI, and XII) and common pathways (I, II, V, and X).
Thrombin time (TT)	12-20 sec	It tests the common pathway (I, and II).
Plasma fibrinogen	150-400 mg/dL	
Bleeding time (BT)	2 – 9 min	It tests platelet function, count and vascular integrity.
Fibrin degradation products	< 10 mg/L (μ g/mL)	It is increased in DIC.
International Normalized	1-1.2	It assesses warfarin therapy

ANESTHESIA WITH BLOOD DISEASES

Ratio (INR)		<ul style="list-style-type: none"> • Therapeutic range for AF, DVT, pulmonary embolism, and tissue heart valves = 2-3 • Therapeutic range for mechanical heart valves = 3-4.5 It assesses factor VII activity (it has a short $t_{1/2}$) so, other factors may be low as II, IX, and X while INR is slightly prolonged (i.e. it represents normalization of factor VII).
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Interpretation of the Coagulation Screen:A) PT and PTT:

Disease	PT	PTT	TT	Fibrinogen	Treatment
1) Advanced liver disease	↑	↑	N or ↑	N or ↓	Vitamin K, FFP and coagulation concentrate
2) DIC	↑	↑	↑	↓	Of the cause, FFP, cryoprecipitate & platelets.
3) Vitamin K deficiency	↑↑	↑	N	N	Vitamin K
4) Oral anticoagulant	↑↑	↑	N	N	As (1)
5) Heparin therapy	↑	↑↑	↑	N	Stop therapy, protamine
6) Hemophilia (factor VIII or IX deficiency)	N	↑	N	N	Factor VIII concentrate or FFP
7) Factor XI or XIII deficiency	N	↑ or N	N	N	FFP
8) Von Willebrand's disease	N	↑	-	-	Factor VIII concentrate or vasopressin
9) Factor VII deficiency	↑	N	N	N	FFP
10) Fibrinogen deficiency	N	N	↑	↓	FFP & cryoprecipitate

B) Bleeding Time

If it is increased, this indicates one of the following;

a- With low platelet count $< 100 \times 10^9$ / liter;

- Thrombocytopenia.

b- With normal or low platelet count; so it either;

- Thromboasthenia (i.e. decreased platelet function).

Or - Von Willebrand's disease.

Thromboelastography (TEG)Idea:

TEG provides a method for evaluation of the whole coagulation system from the initial clot formation to clot retraction or dissolution. It measures the thrombo-dynamic (Visco-elastic) properties of the whole coagulation process over time. The blood is induced to clot under a low shear environment resembling sluggish venous flow.

Indications:

1- It quantitatively and qualitatively assesses the overall coagulation profile.

2- It guides therapy in the form of fresh frozen plasma (FFP), cryoprecipitate, platelets, or anti-fibrinolytics.

The Thromboelastogram:

It is the instrument of the TEG.

Components:

- A rotating piston (pin) is suspended in a cylindrical cup (cuvette) filled with heated blood. The piston is attached to a calibrated torsion wire.
- As clot formation proceeds, the rotation of the piston is affected and characteristic curves are generated (figure 26-1).

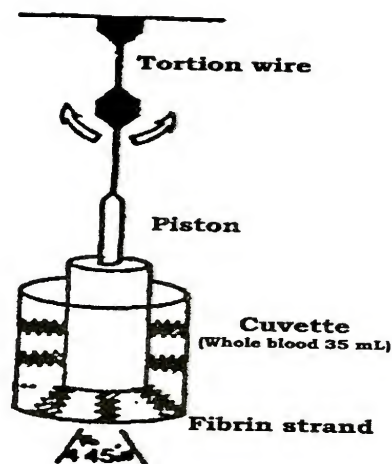




Figure 26-1; TEG




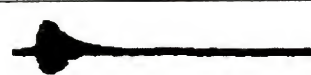
Technique:

- A small sample of blood is placed in the cup and allowed to clot as the cup oscillates through an angle of 45°. Each rotation cycle lasts 10 seconds.
- The elastic shear properties of the sample are measured as fibers composed of fibrin and platelets are formed, and attach the cup to the pin which becomes monitored for motion.
- The strength and rate of these fibrin-platelet bonds affect the magnitude of the pin motion such that strong clots move the pin directly in phase with the cup motion. Thus, the magnitude of the output is directly related to the strength of the formed clot.
- As the clot retracts or lyses, these bonds are broken and the transfer of cup motion is diminished.
- The rotation movement of the pin is converted to a mechanical signal that can be monitored by a computer. The resulting hemostatic profile (curve) is a measure of the time taken for the first fibrin standard to be formed, and the kinetics of clot formation, its strength and dissolution.

Qualitative Analysis of Thromboelastograms:

	Curve
Normal	 The onset The end
Hyper-coagulation	

ANESTHESIA WITH BLOOD DISEASES

Thrombocytopenia	
Heparin	
No platelet function	
Fibrinolysis	

Anesthesia with Blood Diseases

Anemia

Definition: Decreased Hb concentration below the lower limit according to the sex and age.

- | | |
|-----------------------|-------------------------------|
| i.e. for | below; |
| • Adult men: | 12.5 – 18.0 gm/dL (Hct < 40%) |
| • Adult women: | 11.5 – 16.5 gm/dL (Hct < 36%) |
| • 10 – 12 years old: | 11.5 – 14.5 gm/dL |
| • A 1 year old: | 11.0 – 13.0 gm/dL |
| • A 3 month infant: | 9.5 – 12.5 gm/dL |
| • A full term infant: | 13.5 – 19.5 gm/dL |

Causes:

1) Iron Deficiency Anemia: It causes microcytic hypochromic anemia.

Due to nutritional deficiency, or chronic blood loss (e.g. GIT, female genital tract).

2) Anemia of Chronic Disorders: It is of an unknown mechanism.

As • Chronic inflammation: as - Infections (as AIDS).

- Malignancies.
- Uremia.
- Liver diseases especially alcoholic cirrhosis.
- Endocrinal diseases as DM.

3) Megaloblastic Anemia:

a- Vitamin B₁₂ Deficiency:

- Due to a small intestinal disease or resection, or atrophy of gastric mucosa, the **intrinsic factor** is decreased causing **pernicious anemia**. Also **prolonged exposure to N₂O** may cause Vitamin B₁₂ deficiency.

b- Folic Acid Deficiency:

- Due to: Dietary deficiency e.g. pregnancy and alcoholism.

4) Aplastic Anemia: (Depressed bone marrow)

a- **Acquired:** - Chemotherapy.

- Radiotherapy.

- Viral infection.

- Immunological disorders.

- Chloramphenicol.

b- **Hereditary:** - Fanconi syndrome: It is congenital aplastic anemia.

- Diamond-Blackfan syndrome: It is congenital pure erythrocyte aplastic anemia.

- C/P: - Decreased RBCs causing anemia.
- Decreased WBCs causing infection.
- Decreased platelets causing thrombocytopenia.

5) Hemolytic Anemia:

a- Acquired:

- Splenomegaly and hypersplenism.
- Immuno-hemolytic Anemia: due to presence of antibodies against RBCs.

b- Hereditary:

1- Intrinsic Factors:

- Enzyme defects: - **Glucose-6-phosphate dehydrogenase (G6PD) deficiency.**
- Hemoglobinopathies: - Sickle cell syndrome.
 - **Thalassemias.**
 - **Met- and sulf-hemoglobinuria.**

2- Membrane Abnormalities:

- **Hereditary Spherocytosis:**

Due to abnormalities of the RBCs membrane, which allows Na^+ influx resulting in increased osmotic pressure, so, water enters inside the RBCs causing swollen (spherocytic) cells. The cells can not be compressed e.g. via the spleen, causing easy rupture (hemolysis).

Glucose-6-phosphate dehydrogenase (G6PD) deficiency:

- It is an **X-linked** trait (affect males). There is oxidation and phosphorylation of Hb in RBCs due to deficiency of G6PD enzyme resulting in hemolysis.
- Induced by: - Fava beans. - Bacterial viral infections. - Metabolic acidosis.
- Drugs as:

- 1- Analgesics: phenacetin, acetaminophen, aminosalicic acid
- 2- Antibiotics: nitrofurantion, nalidixic acid, penicillin, streptomycin, chloramphenicol, isoniazid, and sulfonamides.
- 3- Anti-malarial drugs.

Others: Probenecid, quinidine, quinine, vitamin K^+ analogues, methylene blue, nitroprusside and prilocaine (the last 2 drugs cause met-hemoglobinemia which can not be treated by methylene blue so, both are also avoided).

Thalassemia: A congenital defect in Hb synthesis which causes hemolysis.

a- **Beta – thalassemia:** It is a defect in the synthesis of the β globin chain of Hb A causing one of the following;

- β – thalassemia trait (minor): due to a heterozygous state causing no or a mild C/P.
- β – thalassemia intermedia: due to a double heterozygous or homozygous state causing a moderate C/P.

• β – thalassemia major (Cooley's anemia) due to a homozygous state causing a severe C/P.

b- **Alpha – thalassemia:** It is a defect in the synthesis of the α globin chain of Hb A causing either;

- α – thalassemia trait: due to a heterozygous state causing a mild C/P.
- α – thalassemia major: due to a homozygous state causing a severe C/P.

C/P: Hemolytic anemia, hepato-splenomegaly, hypersplenism, extra-medullary hematopoiesis causing skeletal changes as cephalo-facial deformities, over-growth of the maxilla (resulting in **difficult intubation**), spinal cord compression, hemothorax. Chronic blood transfusion causes cardiac hemochromatosis (which causes SVT and CHF).

ANESTHESIA WITH BLOOD DISEASES**Anesthetic Management:**

Generally for all types of anemia;

1) Detection of the **type and cause of anemia** and **avoiding it if possible**, pre-, intra- and postoperatively.

2) Detection of the **degree of anemia** and **managing it**.

Hb 10 gm/dL is considered the minimum allowed for elective surgery.

3) **Avoid** factors that interfere with O₂ delivery to tissues;

- **Drug induced decreased CO.**

- **Left shift of the O₂-Hb dissociation curve.**

e.g.: - Respiratory alkalosis due to hyperventilation.

- Decreased body temperature.

Q: Discuss the Anesthetic Management of hemoglobinopathies?

Q: Discuss the Anesthetic Management of hemolytic Anemia?

Sickle Cell Syndrome

Classification:

a) Sick Cell Anemia (SS): with a homogenous gene causing a severe C/P.

b) Sick Cell Trait (AS): with a heterogenous gene causing no or a mild C/P.

c) Other Types:

- Sick Cell Hb C Anemia (SC): either a homogenous or heterogeneous gene.

As Hb S + Hb C (in the latter, glutamic acid in the 6th position of the β chain is replaced by lysine).

- Sick Cell Thalassemia (S β thalassemia): as Hb S + a defect in the beta chain of Hb.

- Sick Cell Hb E Anemia (SE): as Hb S + Hb E (in the latter, there is a single substitution on the β chain).

Pathology of Hb S:

- It is a hereditary hemolytic anemia where the Hb gene is on **chromosome N° 11**. In sickle cell Hb (Hb S), the **glutamic acid** in the 6th position of the normal β chain is **replaced by valine**.

- Under certain conditions especially hypoxia, acidosis,etc, **deoxygenation of Hb S** occurs causing polymerization and binding of Hb S together. So, Hb S becomes less soluble and forms **long crystals** which **distort RBCs** giving them a crescent shape (**sickle shape**). so, **these RBCs have a much shorter survival of 10-15 days** (compared with 120 days in the normal RBCs). Therefore, anemia occurs and a Hct of 18 – 30% is reached.

- These rigid sickle cells tend to **aggregate** in the capillaries and venules **obstructing** the flow of blood with subsequent **infarctions and pain (crisis)**, as well as more acidosis and hypoxia which result in more sickling i.e. a vicious circle occurs.

The sickling Phenomenon depends on:

1) **The Percentage of Hb S (in RBCs) and the Presence of Other Hb**

- A **higher %** of Hb S causes more sickling.

- Presence of **Hb C or E** causes more sickling.

2) **O₂ Tension (Hypoxia):**

- RBCs sickle at a particular level of deoxygenation. So, sickling occurs at:

- SS (homozygous) → Sickling occurs at **40 mm Hg PaO₂** i.e. at the physiologic venous O₂ tension.

- SC → Sickling occurs at **30 mm Hg PaO₂**.

- AS (heterozygous) → Sickling occurs at **20 mm Hg PaO₂** i.e. at very low O₂ level.

3) Acidosis:

- It causes shift of the O₂-Hb dissociation **curve to the right** (i.e. more O₂ is delivered to the tissues) leaving more deoxygenated Hb in RBCs which produces more sickling.

Factors Causing Hypoxia and Acidosis:

- Hypothermia (→ VC) —
 - Dehydration —
 - Over transfusion —
 - Infection —
 - Hypotension —
- They increase blood viscosity causing stasis which in turn causes hypoxia and acidosis.
- hypoxia and acidosis.

Clinical Picture:

- Patients are often black Africans, black Americans, Mediterraneans, Arab and Indians.
- Patients are often young as the C/P appears after disappearance of Hb F.

1) Hemolytic Anemia: It causes jaundice and gall stones, which cause obstructive jaundice also.

2) Crisis: There is periodic exaggeration of symptoms precipitated by stress e.g. infection, cold weather, dehydration etc.

- Types:

a) **Hemolytic crisis**: as stress and infection cause sudden severe hemolysis which result in dyspnea, palpitation, jaundice and dark urine.

b) **Aplastic crisis**: Viral infection or folate deficiency cause BM depression resulting in acute profound aplastic anemia (Hb can reach 2 – 3 gm/dL).

c) **Sequestration crisis**: There is acute massive enlargement of the liver and spleen with pooling of RBCs. It usually affects young children and necessitates immediate transfusion.

d) **Vaso-occlusive (infarctive) crisis**: (the commonest) as sickling causes sludging of RBCs within small vessels. So, infarctions all over the body occur producing;

- **Bone and joints pain**, hand, and feet infarctions (dactylitis), biconcave (fish mouth) vertebrae and osteomyelitis.

- **Chronic leg ulcers**.

- Early **splenomegaly** occurs (sequestration) then later on in life, multiple splenic infarctions cause **asplenia** with loss of function so, repeated bacterial infections occur.

- **Priapism**.

- **Repeated pulmonary emboli** cause chest pain, cor pulmonale, and CHF.

- **Myocardial infarctions**.

- **Hepatic infarctions** which cause hepatic abscesses and fibrosis so, hepatic dysfunction occur.

- **Renal infarctions** as renal papillary necrosis which causes hematuria and renal dysfunction up to renal failure.

- **Cerebral infarctions** and intra-cerebral hemorrhages.

- **Retinal infarctions** and detachment, retinopathy, and vitreous hemorrhage.

3) If associated with **thalassemia**, **skeletal deformities** occur e.g. over growth of the maxilla.

4) Repeated blood transfusions increase iron load causing **hemochromatosis** which causes liver cirrhosis and LV dysfunction.

Investigations:

1) **Blood film**: to detect the presence of sickle cells.

2) **Sickledex**: It is a commercially available macroscopic test that detects Hb S by a precipitation reaction.

3) **Na meta-bisulphate**: a reducing agent that consumes O₂ causing sickling.

ANESTHESIA WITH BLOOD DISEASES

4) **Hb electrophoresis:** a definitive test which detects different Hb types and measures their concentration.

Treatment of Sickle Crisis:

- 1- **Bed rest, sedation and analgesics** (opioids, i.m. or via the epidural route).
- 2- Treatment of **precipitating factors** as - Hypoxia (by O₂).
 - Dehydration (by i.v. fluids).
 - Acidosis (by i.v. NaHCO₃).
 - Infection (by antibiotics).
- 3- **Partial exchange transfusion** with RBCs containing Hb A to increase Hb A up to 50%, but with keeping Hct at < 35%.
- 4- **Hydroxy-urea** stimulates genes that produce **Hb F** leading to clinical improvement.
- 5- **Hyperbaric Oxygen:** It decreases the rate of sickling and improves tissue oxygenation by direct diffusion only in vivo (not in vitro).

Anesthetic Management:

Patients with **sickle cell trait**, show **no risk** with anesthesia, but patients with **sickle cell disease** show **an increased risk** with anesthesia.

Preoperative Management:**1) Preoperative Assessment of the Degree of Anemia:**

- Correction of anemia is done by:

1- Preoperative packed RBCs transfusion to;

- Increase Hb A up to 10 gm% (Hct up to 25 – 30%). Avoid over-correction as a greater increased in Hct, increases the viscosity which increases sickling.
- Suppress endogenous erythropoiesis so Hb S concentration is reduced.

2- Preoperative exchange transfusion (It is controversy)

- To replace Hb S by Hb A so; Decrease Hb S concentration to < 40%.
And increase Hb A concentration to > 50-60% (with a Hct of 30%)

- Indications: when Hb concentration is 6 – 7 gm% especially for **high risk and major surgeries** (minor elective surgeries can be done without exchange transfusion).

2) Preoperative assessment of the precipitating factors and their management

E.g. infections, dehydrations.....

3) Preoperative assessment of the C/P and other organ affections.

E.g. - Chest, heart, cerebral, bone ... etc. - Difficulty of intubation.

4) Premedications:

- Sedatives (and opioids) are better decreased or avoided for fear of hypoxia.

Intraoperative Management:**Aim:**

- 1) **Avoid Hypoxia:** by • Adequate oxygenation (and increasing the FiO₂ to > 0.5).
 - Pulse oximetry and mixed venous O₂ partial pressure monitoring.
- 2) **Avoid acidosis:** by • Hyper-ventilation to avoid respiratory acidosis.
 - NaHCO₃ infusion 0.3 mEq/Kg/hr to increase the alkali reserve.
 - AB gases monitoring.
- 3) **Avoid hypothermia:** by • Increasing OR temperature, warming blanket, warm fluid and gases.
 - Body temperature monitoring.
- 4) **Avoid dehydration:** by • Adequate i.v. volume (avoid overload).
 - CVP and UOP monitoring.

- Monitoring:** Standard + as above.

Care is taken for **suspected difficult intubations.**

- Postoperative complications: **Any type of crisis** can occur so; they need close observation.

- In G6PD deficiency patients, hemolytic anemia occurs.

Sulf-Hemoglobinemia

Pathology: It is the formation of sulf-Hb which can not carry O₂.

Cause: The same drugs causing met-Hb.

The reason why some patients form met-Hb and others form sulf-Hb is unknown.

C/P: as met-Hb.

Treatment:

No response to methylene blue (in contrast to met-Hb) so, the only means of removing sulf-Hb is by the eventual destruction of the affected RBCs.

Coagulation Disorders

Classification:

- a) **Hereditary:**
 - Hemophilia.
 - Von Willebrand's disease.
 - Others.
- b) **Acquired:**
 - Vitamin K deficiency:
 - It decreases vitamin K⁺ dependent factors II, VII, IX, and X, protein C and S synthesis in the liver.
 - It occurs in malabsorption syndrome, pancreatic insufficiency, biliary obstruction, GIT obstruction and rapid GIT transit time.
 - Drug induced (heparin and oral anticoagulants).

Hemophilia

It is a sex – linked recessive disorder affecting males only.

Types:

- **Hemophilia A (Classical Hemophilia):** Its incidence is 1:10 000 males.

Deficiency of factor VIII: C (a qualitative and quantitative defect)

N.B.; **Factor VIII** is formed of 2 parts (2 molecules) each under separate genetic control.

1- **Factor VIII: C:** - It is the smallest part. It has the coagulant activity.

- Defect in this part causes hemophilia A.

2- **Factor VIII R:Ag:** - It is the largest part.

- It acts as a carrier for factor VIII :C and it is important for platelet adhesion.

- It contains both factor VIII antigen and the Von Willebrand factor (vWF).

Both parts are present together in the plasma as a complex.

- Deficiency of this part causes platelet dysfunction and hemophilia A.

- **Hemophilia B (Christmas Hemophilia):** Its incidence is 1:100 000 males.

Deficiency of factor IX

N.B.; Hemophilia C or para-hemophilia: due to deficiency of factor V. It is autosomal recessive.

C/P:

- All hemophilic patients **bleed excessively** in response to **trauma or surgery** especially **hemo-arthritis and deep tissue bleeding**.
- The degree of bleeding severity is related to the degree of factor deficiency:
 - **Mild cases;** with factor VIII level > 30% of the normal average bleed after **major** surgery.
 - **Moderate cases;** with factor VIII level 10 – 15% show hemo-arthritis, **deep tissue** bleeding and muscle hemorrhage.
 - **Intermediate cases;** with factor VIII level 4 – 8%, bleed with **moderate** trauma.
 - **Severe cases;** with factor VIII level 1 – 3% bleed **spontaneously**.

Investigations:

- PTT is prolonged, but the bleeding time and PT are normal.
- Factors VIII (in hemophilia A) or factor IX (in hemophilia B) are decreased.

Treatment:**1) By Factor VIII (or IX) Replacement Therapy:****Indications:**

- 1- Uncontrolled bleeding.
- 2- Preoperative preparation for elective surgery.

Aim:

a- In Hemophilia A: reaching 100% of factor VIII is the ideal (although > 30% is adequate), **1-2 hours before surgery.**

Then maintain: • > 80% → during the 1st 4 postoperative days.

• > 40% → during the next 4 days.

• > 10% → during the next 3 weeks (in severe cases).

Other centers maintain > 50% during the 1st 10 – 14 postoperative days.

b- In Hemophilia B: reaching > 30% of factor IX perioperatively is needed.

Calculation of the Dose:

One unit of factor VIII activity / Kg BW increases plasma, factor VIII levels about 2%.

So; e.g. a 70 kg man with 5% factor, needs to reach 100% factor VIII activity

Factor VIII is needed to be elevated as follows $100 - 5 = 95$

$$\frac{95\%}{2\%} \times 70 \text{ Kg} = 3320 \text{ units of factor VIII are needed to be infused.}$$

N.B.; One unit of factor VIII activity is defined as:

The amount of factor VIII present in one mL of fresh normal pooled plasma.

Interval of Administration:

- For factor VIII; It is given every 12 hours (as the $t_{1/2}$ of factor VIII is 10 – 12 hours).
- For factor IX; It is given every 24 hours (as the $t_{1/2}$ of factor IX is 18 – 24 hours).

Route of Administration:

- a- **I.v. bolus** administration (not preferred)
- b- **I.v. infusion** is preferred because; It avoids inhibition by antibody inhibitors because most of the inhibition occurs after 1 – 2 hours of factor VIII administration. So, on continuous infusion some of factor VIII will be circulating and un-neutralized and still active. Therefore, the infusion technique is **more effective**.

Forms of Factor VIII and IX:**1) Fresh Frozen Plasma (FFP):**

- It contains **0.7 – 0.9 units** of factor VIII activity/mL.
- There is risk of transmission of - Hepatitis B → 1: 200 000
 - Hepatitis C → 1: 3300
 - AIDs → 1: 450 000 – 660 000

2) Cryoprecipitate:

- It is the fraction of plasma that precipitates when FFP is thawed.
- It contains **5 – 13 units** of factor VIII activity/mL.
- Advantages: • Readily available.
 - Long shelf life.
 - Relatively low risk of hepatitis and AIDs (but still present).

ANESTHESIA WITH BLOOD DISEASES

- It contains also fibrinogen, fibronectin, and vWF.
- Disadvantages:
 - Allergic reactions.
 - Rh sensitization, as it contains RBCs fragments, so, it can sensitize Rh -ve individuals to Rh antigens if the donor is Rh +ve.

3) Heated – Treated Lyophilized Factor VIII Concentrate:

(Also factor IX concentrate is available)

- It contains **40 units** of factor VIII activity/mL.
- Advantages:
 - Easily stored and reconstituted.
 - Long shelf life.
 - Known potency.
- Disadvantages:
 - Still the risk of hepatitis and AIDs is present but reduced.

4) Recombinant or Monoclonal Purified Factor VIII (and factor IX):

- Advantages:
 - There is no risk of hepatitis or AIDs (biologically safe).
 - Stable.
- Disadvantages:
 - High cost.

2) DDAVP (Desmopressin):

Action: It is a synthetic analogue of ADH which causes release of factor VIII: C from endothelial cell storage sites.

Disadvantages: It can not be repeated because such stores become depleted as factor VIII: C's half life is only 12 hours.

Anesthetic Problems:

1) **Elective surgeries (even minor)** should be carried out only in **designated hemophilia centers** which have the staff, technical facilities and experience necessary to supervise and manage these patients.

Emergency surgeries should be done under the advice and supervision of the hematologist at the nearest designated center.

2) **Preoperative management** as above.....

3) **Premedications: avoid all i.m. injections** so; only use oral or i.v. routes (although factor VIII activity > 30 – 50% is considered safe for i.m. injections).

4) **25%** of hemophilic patients have antibodies to **HIV virus and hepatitis virus** so, take all precautions (e.g. avoid drugs that affect liver disease in anesthesia).

5) **Avoid any trauma** during anesthesia; So,

- All forms of **regional anesthesia are contraindicated** (there are some reports of succeeded axillary block in these patients).
- During airway management;
 - Careful **placing of the mask** is needed to avoid pressure trauma to the lips, tongue and face.
 - **Laryngoscopy** is done **after complete muscle relaxation** only by **skilled clinician** using a **curved blade (less traumatic)**.
 - **ETT** should be **small and well lubricated**.
 - **Avoid nasal intubation**.
 - **Gentle oral suction** under direct vision before extubation is done.
- Postoperative pain control: **Avoid NSAIDs** (only use opioids or paracetamol).
- **Postoperative factor VIII concentrate maintenance** as above(it is given while the patient is in the hospital or at home).

Von Willebrand's Disease

Incidence: 2 – 3% heterozygous trait (the most common inherited bleeding disorder).
1:10 000 homozygous trait (as hemophilia A)

C/P: As hemophilia A.

Bruising and mild bleeding on trauma (e.g. epistaxis) or after surgery, but hemo-arthritis and deep tissue bleeding are uncommon.

Investigations:

- 1) **Prolonged bleeding time, but normal platelet count.**
- 2) **Decreased vWF concentration.**
- 3) **Decreased Factor VIII activity** as vWF acts as a carrier for it.

Treatment:

- 1) **vWF replacement:** by FFP, cryoprecipitate or factor VIII concentrate.
- 2) **DDAVP:** It evokes the release of vWF from storing sites. (see before.....)

N.B.: Reversal of Anticoagulated Patients (on Oral Anticoagulants)

Before Surgery: By:

1) Phytomenadione (Vitamin K₁):

- Dose: 5 mg i.v. is usually given, but 0.5 – 1.0 mg i.v. is sufficient to return INRs to its target within 24 hours.

- Duration of reversal: 12 – 24 hours (it can not be hastened by a larger dose). If excessive vitamin K₁ is given, it may render the patient refractory to further warfarinization for days or weeks.

2) If a more rapid reverse is required (for emergency surgery);

• **FFP:** up to 1 liter (5 units), group O or group A FFP is used.

• **Vitamin K Dependent Factor Concentrates:** containing factor II, VII, IX, and X at a dose of 50 µg/Kg.

It is unwise to fully reverse anticoagulation in patients with prosthetic heart valves. A cardiologist advice is required.

Hyper-Coagulable States

	Protein C deficiency	Anti-thrombin III deficiency
Cause	<ul style="list-style-type: none"> - Protein C is a vitamin K⁺ dependant anticoagulant synthesized in the liver causing • Inhibition of activated factors V and VIII. • Stimulation of fibrinolysis. <p>So; its deficiency causes hyper-coagulation, and is either:</p> <ul style="list-style-type: none"> a- Inherited. Or b- Acquired: e.g. liver diseases, DIC, adult respiratory distress syndrome, postoperatively, postpartum, and hemodialysis. 	<ul style="list-style-type: none"> - Anti-thrombin III (AT-III) causes; • Inhibition of activated factors II and V. <p>So, its deficiency causes hyper-coagulation and is either:</p> <ul style="list-style-type: none"> a- Inherited. Or b- Acquired: e.g. liver diseases, DIC, drugs as heparin, oral contraceptive pills (estrogen type).
C/P	<ul style="list-style-type: none"> • Recurrent thrombo-embolic diseases as myocardial or cerebral infarctions and pulmonary embolism. • Resistance to the anticoagulation effect of heparin. 	
Investigation	<ul style="list-style-type: none"> • Routine coagulation tests (PT, PTT, BT) are normal. 	<ul style="list-style-type: none"> • Decreased AT-III concentration in the plasma.
Treatment	<ul style="list-style-type: none"> • Oral anticoagulants to prevent thrombosis. • Regional anesthesia is preferred because GA increases coagulation • FFP 	<ul style="list-style-type: none"> • Oral anticoagulants. • AT-III administration as AT-III concentrates, or FFP for acute management.

Hyper- Coagulability

A) Venous Hyper-Coagulability:

DVT occurssee Anesthesia for Respiratory Diseases.

B) Arterial Hyper-Coagulability (Thrombosis)

Risk Factors:

1- Vascular Injuries.

N.B.; Other components of Virchow's triad (i.e. stasis and hyper-coagulability as anti-thrombin or protein C deficiencies) are not risk factors in arterial thrombosis.

2- Critical Atherosclerotic Lesions: They produce a high shear flow and activate platelets.

3- Genetic Factors:

- Enhancement of the function of the platelets causing more thrombosis.

C/P:

Arterial thrombosis: • Cerebral thrombosis resulting in cerebral stroke,
• Coronary thrombosis resulting in myocardial infarction.

Thrombocytopenia & Thromboasthenia

Definition:

- **Thrombocytopenia:** It is decreased platelet count $< 100- 150 \times 10^9 / \text{Liter}$.
- **Thromboasthenia:** It is platelet dysfunction.

Causes:

A) Causes of Thrombocytopenia:

a- Congenital: May – Hegglin anomaly. It is autosomal dominant.

b- Acquired:

1. Idiopathic (Autoimmune) Thrombocytopenic Purpura (ITP):

Due to anti-platelet immunoglobulins that bind to the platelet membrane causing premature destruction. So, it is treated by corticosteroids e.g. prednisone, immuno-suppressives e.g. vincristin and splenectomy.

2. Bone Marrow Infiltrations e.g. leukemia or myeloma.

3. Blood Transfusion: due to;

- **Abs against platelets:** It causes post-transfusion thrombocytopenia which occurs 2 – 10 days after whole blood transfusion.
- **Stored massive blood transfusion:** as it contains a small platelet count. After 3 days storage, only 20% of platelets are alive.

4. DIC: see later.....

5. Catheter Induced Thrombocytopenia:

It occurs especially with a **PA catheter** of polyvinyl chloride material which is thrombogenic, causing thrombus formation which produces platelet consumption despite of the heparin saline used. So, a heparin bonded PA catheter is used now.

6. Thrombotic Thrombocytopenic Purpura (TTP):

It is accompanied with disseminated intravascular aggregation of platelets causing thrombocytopenia, severe hemolytic anemia, focal cerebral lesions up to coma and fits, fever and jaundice. Mortality is 60 – 80% in the 1st 10 days of the disease. It is treated by anti-platelets and exchange plasmapheresis.

B) Causes of Thromboasthenia:

a- Congenital: Von Willebrand's disease.

b- Acquired:

- Uremia.

- Liver failure.
- CP bypass: As there is change in the media in which platelets circulate.
- DIC: As there is consumption of the platelets.
- Leukemia and other myelo-proliferative or myelo-dysplastic syndromes.
- Massive transfusion of stored blood: As there is platelets dysfunction due to depletion of energy stores especially ATP which return to normal function after 8-20 hours.
- Drug induced:
 - NSAIDs e.g. acetylsalicylic acid (aspirin), phenylbutazone or indomethacin which decrease PG synthesis by irreversible inhibition of cyclo-oxygenase enzyme (important for platelet release of ADP). The effect occurs 3 hours after one tab of 300 mg aspirin and lasts 2 weeks. So, **stop NSAIDs 2 weeks before surgery.**
 - Dipyridamole - Dextran - Heparin - Alcohol
 - Antibiotics as high dose penicillins or some cephalosporins.

C/P:

- 1) **Petechial purpura** at the site of the usual trauma as below the knees, those oral mucosa (with blood filled blisters), constricting clothing sites.....etc.
- 2) Eyes: **Fundal hemorrhage.**
- 3) CNS: **intracranial hemorrhage.**
- 4) **Oozing** at the operation and venepuncture site.
- 5) ITP: Trans-placental passage of Abs occurs causing **neonatal hemorrhage.**
TTP: Thrombus formation and hemolytic anemia occur.

Investigation:

There is **prolonged bleeding time.**

If there is a **decreased platelet count** so, it is **thrombocytopenia.**

If there is a **normal platelet count** so, it is **thromboasthenia.**

Treatment:

- 1) Treatment of the cause.
- 2) Platelet transfusion: 1 unit for each 10 kg body weight.
- 3) Desmopressin for platelet dysfunction.

Disseminated Intravascular Coagulation

(DIC) (Consumption Coagulopathy)

Definition:

Inappropriate triggering of the coagulation cascade in flowing blood by specific disease processes.

Cause:

- **The coagulation cascade is activated by:**
 - 1- Release of endogenous tissue **thromboplastin or thromboplastin-like substances** from hypoxic acidic tissues.
 - 2- Direct activation of factor XII by **endotoxins or foreign surfaces** causing widespread deposition of fibrin in the microcirculation leading to;
 - **Consumption of coagulation factors and platelets** (i.e. thrombocytopenia).
 - **2ry fibrinolysis** stimulation with changing of plasminogen in to plasmin which digests fibrinogen fibrin-degradation products.
- **Micro-angiopathic hemolytic anemia.**
- **Diseases associated with DIC:**
 - 1) **Obstetrics** e.g. eclampsia, placental abruption, retained placenta, intrauterine fetal death and amniotic fluid embolism.

ANESTHESIA WITH BLOOD DISEASES

- 2) **Tissue trauma** e.g. crush injuries, head trauma, severe burn, and extensive surgery.
- 3) **Severe infections** e.g. malaria, gram -ve septic shock, and viruses.
- 4) **Ag-Ab complexes** e.g. incompatible blood transfusion.
- 5) **Disseminated malignancies** e.g. acute leukemia.
- 6) **Malignant hyperthermia.**
- 7) **Fat embolism, pulmonary embolism.**
- 8) **Prolonged extracorporeal circulation.**
- 9) **Severe shock.**

C/P:

- **It varies in severity** from diffuse bleeding or a thrombo-embolic phenomenon, to only a laboratory sign with no clinical manifestations.
- **Bleeding** is usually observed from wound sites and i.v. cannulas.
- It should be considered **a sign of another disease rather than a disease** so, the **C/P** of the cause is present.

Investigations:

- 1) **Hypo-fibrinogenemia:** S. fibrinogen decreases < 150 mg/dL.
- 2) **Increased fibrin degradation products (FDPs).**
- 3) **Thrombocytopenia and thromboasthenia prolong the bleeding time.**
- 4) **PT, PTT, and TT are prolonged** due to;
 - Consumption of clotting factors I, II, V, and VII.
 - Anticoagulant effects of FDPs.
- 5) **Blood film examination** shows **RBCs distortion and fragmentation** if there is associated micro-angiopathy.
- 6) **D-dimers Assessment:** the most sensitive and most specific test.

Treatment:

- 1) Treatment of the **cause** e.g. antibiotics for infection, evacuating the uterus, i.v. fluids for shock.
- 2) Supportive treatment (**replace blood components**) under the advice a hematologist as;
 - FFP
 - Cryoprecipitate
 - Platelets
- 3) **Heparin:** is **controversial** as it may be beneficial in patients with thrombo-embolic phenomenon.

CHAPTER 27

ANESTHESIA FOR PEDIATRIC PATIENTS

Differences Between Pediatric Patients and Adult

A. Physiologic Changes:

Age	Respiratory rate	Heart Rate	Systolic BP	Diastolic BP	Blood Volume mL/Kg
• Neonate (<30 days age)	32-40	140	65-80	40-45	90 100-120 in preterms
• Infant (1-12 months)	30	120	95	65	80
• Child (1-12 years)					
1 – 3 years	25	100	100	70	80
12 years	20	80	110	60	75 (As adult ♂) (N.B.; Adult ♀ =65)

Most organs are **immature** and there are **increased metabolic needs**.

1- CVS:

- **CO** is relatively **high** due to the high metabolic rate (2-3 times that of the adult) (200mL/Kg/min). **CO** is **HR dependent** as the stroke volume is fixed by the poorly developed L.V.

- **HR** is **faster**. Babies can **tolerate HR up to 200 beats/min** without evidence of heart failure, **bradycardia readily occurs** in presence of hypoxia or vagal stimulation (so, it needs rapid treatment with O₂ and atropine).

- **ABP** is **lower** due to low systemic vascular resistance due to the large proportion of vessel-rich tissues in children. The vessels are less able to respond to hypovolemia by VC so, the hallmark of **hypovolemia is hypotension without tachycardia** because the sympathetic nervous system and the baroreceptor reflexes are not fully mature.

- **Cardiac arrest** usually occurs in **asystole** rather than ventricular fibrillation.

2. Respiratory System:

- **Increased alveolar minute ventilation** due to increased metabolic rate (increased O₂ consumption and CO₂ production) so,

• Rapid induction and recovery from inhalational agents occur.

• There is limitation of O₂ reserve during periods of apnea e.g. during intubation.

- **Lower lung compliance and greater chest wall compliance** (due to the cartilaginous chest wall).

- **Airway** is relatively **narrow** up to 6-8 years old increasing airway resistance which increases the incidence of respiratory diseases.

- Respiratory rate (RR)/min for age between 1-13 years = $24 - \text{Age}/2$

RR is faster due to • Low lung compliance.

• High airway resistance.

- Due to immaturity of control of ventilation, hypoxic and hypercapnic ventilatory drives are not well developed in neonates and infants as **hypoxia and hypercapnia depress respiration (unlike in adults)**.

3. CNS:

- CNS is still immature.
- BBB is more permeable.
- At birth, myelination is incomplete.

All these factors increase the sensitivity to lipid-soluble drugs.

4. Hematologic System:**- Blood volume:**

- At birth, it varies up to $\pm 20\%$ of blood volume depending on the stage at which the cord is clamped.
- It varies with age as above.

- Hematocrit and Hb:

	Hct (%)	Hb (gm %)
Full term neonate	55	18.0
3 months infant	32	10.7 (physiologic anemia).
6 months infant	36	12.3 (It increases again).

- Hb type:

- At birth, 75% is Hb F which has high O₂ affinity (due to low content of 2, 3 DPG), low PaO₂, poor tissue unloading i.e. Oxy-Hb dissociation curve is shifted to the left (P50 = 19 mm Hg).
- At 6 months of age, 100% of Hb is Hb A which has a low O₂ affinity, high PaO₂ and good tissue unloading.

- All coagulation tests in neonates are increased (including PT and PTT), except the BT which is normal, but the coagulation rate is normal due to the decreased naturally occurring anticoagulants.

5. Kidneys:**- Na⁺ and water:**

As kidneys are immature at birth (GFR and tubular reabsorption are decreased) so;

- They are unable to handle excessive water loads and Na⁺ loads so, over-transfusion may cause pulmonary edema and CHF.
- Neonates are obligate Na⁺ losers and cannot concentrate urine as effectively as an adult so; exogenous Na⁺ and water should be supplied during the perioperative period.

- GFR: It increases gradually with age.

- Excretion of drugs and glucose:

As the kidneys are immature at birth; there is;

- Impaired excretions of drugs (e.g. digoxin, and penicillin) causing cumulation and toxicity so; decrease doses or increase intervals in neonates.
- Abnormal increased excretion of glucose with tendency toward hypoglycemia.

N.B.; Hypoglycemia is defined as: < 25 mg/dL in the prematures.

< 30 mg/dL in the neonates.

< 40 mg/dL in older children.

< 50 mg/dL in adults.

6. Liver:

- The liver is immature so; there are;

- Immature enzymes responsible for glucuronidation decrease the metabolism of opioids and chloramphenicol which increase the risk of toxicity.
- Immature liver microsomal enzymes causing extreme rarity of halothane-related hepatic damage in children under 10 years of age.

7. GIT:

- Lower gastric pH (< 2.5) than in adults.

- Higher residual volume in the stomach than in adults.

FLASHLIGHTS ON ANESTHESIA

But, several studies have demonstrated that higher gastric pH and lower residual volumes existed in pediatric patients who received clear fluids a few hours before induction.

8. Fluid Balance:

- **Higher total body water content 70-80% (adult 50-60%).**
- **ECF ratio exceeds that of ICF ratio, this ratio is reversed gradually with increased age while the plasma volume remains constant.**

Age	ECF%	ICF%	Plasma %	Total %
Neonate	35	40	5	80
Infant	30	40	5	75
>2years and adult	20	40	5	65

- **The turnover of fluids** is much greater in infant 15% total body water per day than in the adult. So; interruption of fluid intake in infants leads to rapid dehydration

9. Temperature Regulation:

- Heat loss is increased in pediatrics due to;
 - **Surface area to volume ratio** is 2.5 times > adults so; this causes more heat loss.
 - At birth, **subcutaneous fat is minimal** (almost absent in the premature) so; natural isolation is poor.
 - At birth, **skin keratinization is minimal** so, there is increased evaporative heat loss.
- Heat loss occurs by
 - Conduction.
 - Convection.
 - Evaporation from the skin and respiratory tract.
 - **Radiation (70%)** to near by surfaces e.g. walls of incubator.

- Methods of heat production:1. **Infants < 3 months old:** depend on **non-shivering thermogenesis**.

• As there is an **increased metabolism of brown fat** which is present in the neck, upper thoracic area, inter-scapular area, vertebral areas and around the great vessels and the kidneys. It is controlled by the sympathetic nervous system.

• It is inhibited by volatile anesthetics.

• It is limited in premature infants and sick neonates due to defective fat stores.

2. **Older children:** depend on **muscle shivering thermogenesis**.

Both increase O₂ consumption which exerts more stress on the immature respiratory system leading to respiratory failure.

- Effect of hypothermia:

1. Respiratory depression.
2. Decreased CO, increased pulmonary vascular resistance and decreased HR.
3. Decreased hepatic metabolism of drugs so, their actions are prolonged e.g. muscle relaxants.
4. Delayed awakening from GA which increases the risk of aspiration in the postoperative period.
5. Due to thermogenesis, there is
 - Increased O₂ consumption.
 - Increased CO₂ production and metabolic acidosis.
 - Increased glucose utilization causing hypoglycemia.

- Methods decreasing heat loss:1. Elevate the temperature of the operating room to **thermo-neutral temperature**.

N.B.; - **Neutral temperature:** is the ambient temperature that results in the **least O₂ consumption**.

- **Critical temperature:** is the ambient temperature below which an unclothed, un-anesthetized person can not maintain a normal core body temperature.

Age	Neutral temperature	Critical temperature
Preterm	34°C	28°C
Term	32°C	23°C
Adult	28°C	1°C

2. **Wrapping** the limbs in orthopedic wool or paddling.
3. Warming **blanket** and warming lights.
4. Warming **i.v. fluids** by blood warmers.
5. Warming and humidifying **inspired gases** to decrease heat loss by evaporation.
6. **Overhead radiant heaters** (as in modern IC incubators), but they are not suitable for surgery.

B. Anatomical Changes:

1. CVS:

- **LV** is non-compliant and **poorly developed**.
- **Residual fetal circulation may be present so**, remove all air bubbles from the i.v. lines as this may increase the incidence **paradoxical embolism in the presence of a patent foramen ovale**.
- **Difficult venous access** (due to excessive fat) may be present so, 24 gauge over-the-needle catheters are adequate if blood transfusion is not anticipated.
In emergency cases, when i.v. access is impossible, fluids can be effectively infused via an 18-gauge needle inserted into the medullary sinusoids within the proximal or distal end of the tibia (**inter-osseous infusion**).
- In **arterial cannulation** for AB gases samples, the **right radial artery** is often chosen in neonates as it is in a **preductal position** so; it mirrors the **O₂ content of the carotid and retinal arteries** (especially if there is fear of retrolental fibroplasia of the premature).

2- Respiratory System:

- **Weak intercostal and diaphragmatic muscles** may be present.
- Relatively **narrow airway** up to 6-8 years old may be present which increases the airway resistance increasing the incidence of respiratory diseases.

3. Airway:

- **Difficult mask ventilation and intubation** which may become easier in the neutral and flexed position (rather than hyper-extended as in adults) because;
 1. **Head:** is **larger with a prominent occiput** that tends to place the head in a flexed position before intubation so, if intubation is difficult, slightly elevate the shoulders with towels and place the head on a dough nut shaped pillow. This will make the intubation much easier.
 2. **Oropharynx:** Large tongue, **long and pendulous U-shaped (infantile) epiglottis**, prominent adenoids and tonsils and narrow nasal passages therefore, infants are **obligate nasal breathers (up to 2-6 months old)**.
 3. **Nasopharynx:** narrow nasal passages.
 4. **Larynx:**

	Newborn	Adult
Length	4 Cm	10-13 Cm
Shape	Funnel	Cylindrical
Position of the glottis	At C ₃₋₄ vertebrae	At C ₆ vertebra
The narrowest point	1 cm below vocal cords (Cricoid cartilage)	At vocal cord (glottis)
Vocal cord direction	Slanting anteriorly and cephalad	Transverse or slightly slanting posteriorly
Mucous membrane	Loose so it swells easily	More firmly bound

5. **Trachea:** It is shorter and smaller in diameter so; **easily affected by edema**.

C. Pharmacologic Changes:

Pediatric drug doses are according to the **body weight** which is estimated as follows:

- Neonate = 3 Kg
- 4 Months = 6 Kg
- 1-8 years = age x 2 + 9
- 9 - 13 years = age x 3

FLASHLIGHTS ON ANESTHESIA**1. Inhalational Agents:**

- **Rapid induction and recovery** due to;
 - High ratio of minute ventilation to FRC causing higher alveolar ventilation.
 - Large vessel- rich group.
 - Immaturity of CNS.
 - High metabolic rate.
- **MAC:**



- It is lower in neonates than infants, then it increases gradually during infancy and then it decreases gradually with age till it reaches adult MAC.

i.e. **MAC is higher in infants** than in adults (and neonates) due to:

- **Increased progesterone and beta endorphins** levels in neonates so, they need less MAC.
- **Immaturity of CNS** in infants than adults so, they need higher MAC.
- **Higher metabolic rate** in infants than adults so, they need higher MAC.

Age	Halothane	Enflurane	Isoflurane	Desflurane	Sevoflurane
Neonates	0.87	1.9	1.6	8.0-9.0	3.2
Infants	1.1-1.2	2.0	1.8-1.9	9.0-10.0	3.2
Small child	0.87	1.9	1.6	7.0-8.0	2.5
Adult	0.76	1.7	1.15	6	2.0

- **Sensitivity to myocardial depressive action of volatile agents:**

It is **higher in children** (causing more hypotension) due to undeveloped compensatory mechanisms (VC and tachycardia). So, close monitoring is needed.

- Prepubertal children (< 10 years) are at a much **less risk for halothane induced hepatic dysfunction** than adults due to immaturity of the liver microsomal enzymes.

2. I.v. Agents:

- **Barbiturates and opioids** are more toxic in neonates than in adults so; they need lower doses due to:

- Easier entry across BBB.
- Decreased metabolic capacity as there are immature enzymes responsible for glucuronidation in the liver.
- Increased sensitivity of the respiratory center.

- **Ketamine 2 mg/kg i.v. or 10 mg/kg i.m.**

- Neonates have **increased resistant** to it due to the relatively **high rate of metabolism** and elimination due to the high hepatic blood flow.
- Presence of **secretions** or an airway in the mouth may cause laryngospasm due to increased airway reflex activity.
- **Psychic phenomena** associated with emergence from ketamine are **less in children** than adults. they can be decreased by premedication with midazolam.

- **Propofol 2 mg/kg i.v.**

- It is painful on injection.
- It is **not recommended for children < 3 years old** as it causes severe neurological depression.

- **Etomidate:**

- It is painful on injection.
- It is **not recommended for children** for TIVA.

3. Muscle Relaxants:

- **Suxamethonium:**

- Infants need **larger doses** (2 mg/kg) than adults (1 mg/kg) due to their larger volume of distribution (expanded EC space).
- Infants are more prone to - Myoglobinemia and malignant hyperthermia.
- Arrhythmias (bradycardia) so, i.v. atropine is given 1st

- Hyperkalemia.

So, in elective pediatric surgery, some avoid the use of suxamethonium routinely.

- Non-depolarizing muscle relaxants:

- Generally, children need **initial larger doses** than adults but, there are variable effects due to; - Immaturity of the NMJ especially in premature neonates (they show increased sensitivity).

- Expanded EC compartment which dilutes the drug concentrations.

So, doses should be monitored with a nerve stimulator.

- **Pancuronium**: it causes tachycardia which is a disadvantage in children who normally have a rapid HR so; it should be **avoided**.

Fluid Therapy in Pediatrics

A. Normal Daily Maintenance Requirement:

- **Amount:**
 - 1st up to 5th day of life → 75 mL/Kg/day.
 - 6th day → 100 mL/kg/day.
 - 7th day → 120 mL/Kg/day.
 - > 7th day up to 1 month → 150 mL/Kg/day.
 - In later age → 1st 10 Kg BW: 100 mL/Kg/day.
+ 2nd 10 Kg BW: 50 mL/Kg/day.
+ Each remaining Kg: 25 mL/Kg/day.

N.B.; Fluid intake should be increased by **10%** during **surgeries, pyrexia (fever)**, for babies under **radiant heater**, or in **hot weather**.

- **Type of Fluids:**

- **D₅ 1/4 NS** is used for neonates and infants (up to 1 year) due to their limited ability to handle Na⁺ loads.
- **D₅ 1/2 NS + 20 mEq/L KCl** or **1/2 strength compound Na⁺ lactate** are used for older children.
- Some give **full strength compound Na⁺ lactate (lactated ringer)** especially if there are increased losses.
- All fluids should contain **5% glucose to avoid hypoglycemia** (due to increased metabolic rate).

B. Perioperative Fluid Requirements:

I. Preoperative Deficits:

- Calculated maintenance (see later) x preoperative fasting hours.
50% are given in the 1st hour of surgery.
25% are given in the 2nd hour of surgery.
25% are given in the 3rd hour of surgery.

II. Maintenance Replacement:

- It is calculated as the 1st 10 Kg BW: 4 mL/Kg/hour.
+ the 2nd 10 Kg BW: 2 mL/Kg/hour.
+ Each remaining Kg: 1 mL/Kg/hour.
- Type: as above.

III. Replacement Requirement for Losses:

1. 3rd Space Loss:

- It is impossible to be measured so, it must be estimated by the extent of the surgery.
 - For relatively **atraumatic surgeries** (e.g. strabismus correction): **2 mg/kg/hour**.
 - For relatively **traumatic surgeries** (e.g. abdominal surgery): **6-10 mg/kg/hour**.
- By: Lactated ringer's solution.

FLASHLIGHTS ON ANESTHESIA**2. Blood Loss:**

- Blood loss > 10% in pediatrics (> 20% in adult) should be **replaced with blood**.

N.B.; Ca^{++} is needed to avoid hypocalcemia.

The **accepted lower limit of Hct** is; 30% in neonates (40% in critically ill neonates).
25% in children.

This is to avoid blood transfusion risks.

- Blood loss < 10% can be replaced with either;

- Non-glucose containing **crystalloids** e.g. lactated ringer **3 mL for each 1 mL** of blood lost.

Or • **Colloid** solutions e.g. 5% human albumin **1 ml for each 1 mL** of blood lost.

- Due to the small blood volume, careful blood loss monitoring is achieved by weighing swabs and graduated containers for suction.

- Due to the relatively immuno-compromised state of the neonates, blood products should be; • **Leuko-filtered** to decrease cytomegalovirus and other virus transmission.

- **Irradiated** to prevent lymphocyte proliferation to decrease graft-versus host diseases.

3. Other Losses: Should be replaced e.g. nasogastric suction, urine, diarrhea, and vomiting.

Pediatric Anesthetic Techniques

Preoperative Management:

Preoperative Preparation: Standard +

1. Establish physician-patient relationship to reassure the frightened child.

By • Explaining the process of anesthesia and surgery in age appropriate terms according to the patient's age.

- Bringing an anesthesia mask for the child to play with during the interview

- Someone the child trusts (e.g. a parent) remains in attendance during pre-anesthetic preparations and induction of anesthesia.

2. Assessment for common diseases in pediatrics: e.g.

- **Pyrexia** (may indicate infection).

- **Viral** infections e.g. measles, and chicken pox.

In both, **postpone elective surgeries**, but **proceed with emergency surgeries**.

• **Upper respiratory tract infection (URTI):**

- It increases the incidence of laryngospasm (5-folds) and bronchospasm (10-folds).

- Some authors recommend the following;

- Children with **clear running nose** and cough that has developed within the last 24 hours \pm long surgery or intubation \rightarrow **proceed**.

- Children with **URTI** undergoing short duration surgeries < 20 min with **no intubation** \rightarrow **proceed**.

- Children with **URTI** (purulent rhinitis and productive cough) undergoing long duration surgeries > 20 min with **intubation** \rightarrow **postpone elective surgery for 1-2 weeks**.

- Significant **URTI** (last 3-7 days) with fever ($> 38^{\circ}\text{C}$), cough, rhonchi, wheezing, and malaise i.e. acutely ill child \rightarrow **postpone surgery and wait 4 weeks after disappearance of C/P** to do elective surgeries.

3. Estimation of the body weight (or measure the body weight of the patient) for drug dosage calculation as above.

4. Examination for venous access difficulty.

5. Preoperative fasting periods (NPO)

- Appropriate fasting times:

- No solids, milk formula or bottle feeding → for 6 hours preoperatively for children > 6 month age.
- No solids, milk formula or bottle feeding → for 4 hours preoperatively for children < 6 month age.
- No breast feeding → for 4 hours preoperatively.
- Clear fluids are allowed (and should be actively encouraged) up to 2-3 hours preoperatively (up to 10 mL/Kg).

These recommendations are for healthy neonates, infants and children without risk factors for decreased gastric emptying or aspiration.

- Avoid prolonged fasting as it causes;
- Dehydration and hypovolemia.
 - Hypoglycemia.

6. Premedications:

• Sedatives:

- For neonates, infants and outpatient cases, sedatives are usually omitted.

Older children who exhibit uncontrollable separation anxiety, should receive good sedation.

Patients with **congenital heart disease**, should receive sedatives to prevent perioperative crying as it is associated with increased O₂ consumption, pulmonary VC and hyper-cyanotic episodes.

- e.g.:

Route	Drug	Dose
Oral: - Via oral trans-mucosa - Via GIT absorption (Mixed in a small volume of flavored drink)	Fentanyl Oralet Ketamine Midazolam Diazepam Chloral hydrate	10-15 µg/Kg (onset 10 min of completion) 5-10 mg/Kg 0.25-0.5 mg/Kg 0.2-0.4 mg/Kg 50-100 mg/Kg (maximum 2g/day)
I.m.	Ketamine Midazolam	2 mg/Kg. 0.1-0.15 mg/Kg
I.v.	Morphine Ketamine Midazolam	0.1 mg/Kg 0.25-0.5 mg/Kg 0.02-0.03 mg/Kg
Nasal	Ketamine Midazolam Sufentanil	As i.m. dose 0.1-0.3 mg/Kg
Rectal	Thiopental Methohexitol Ketamine Midazolam Chloral hydrate	30-44 mg/Kg 5-10% solution (given in presence of the parents) to induce sleep for children < 20 Kg within 5-10 min, then the child is taken to OR for a steal induction. It may cause airway obstruction. 25-30 mg/Kg 5-10% solution (as thiopental). As oral dose. As oral dose. As oral dose.

• Anticholinergics:

- They act as • **Anti-sialagogue** (it is important because of the small airway and tubes).

• **Decreasing the like-hood of bradycardia** (common in children).

e.g. Atropine 0.01 – 0.02 mg/Kg i.m. (if no fever), i.v. oral (as i.m. route) or rectal.

Glycopyrrolate 0.01 mg/kg i.v. (less tachycardia than atropine).

• Antibiotics:

Especially in - Premature.

Or - Congenital heart disease.

FLASHLIGHTS ON ANESTHESIA**Intraoperative Management:****Monitoring:** better before induction.**1. The most important** single method of **monitoring** is **direct observation** of the patients as;

- Patient's **color** (cyanosis or pallor).
- Patient's **movement or lacrimation** (with light anesthesia).
- Patient's **respiratory pattern** (with respiratory obstruction).

Using a clear plastic drape permits observation of the patient during head and neck surgery instead of normal drapes which totally obscure the small patient.

2. The stethoscope: Precordial (before induction) or **esophageal** (after induction).

- It is the **most important single monitoring device**.
- To monitor HR, rhythm and intensity (**in infants, the intensity of heart sounds indicates the stroke volume and so the CO**).

3. ECG: For **arrhythmias** which are mainly due to abnormal cardiac rhythm (and not due to myocardial ischemia) so; **lead II** (and not precordial leads e.g. V₅) is the most important to be monitored.

4. Non-invasive ABP:

Use a **suitable cuff size** as a too small cuff causes false high readings (and vice versa).

5. Pulse Oximetry:

It is important because the patient may be completely covered so, it is difficult to assess the skin color.

6. End tidal CO₂ (Capnography):

It gives low ET CO₂ reading in infants and neonates because;

- Small tidal volumes and high inspired gas flows cause dilution of the exhaled CO₂ concentrations.
- A large gas leak around the tracheal tube (as no cuff) may be present.

7. Temperature: It is very important.

- By;
- Skin temperature: with axillary probe (for short procedures).

Core temperature: with rectal, esophageal or nasopharyngeal probes. Avoid external auditory meatus probe as may easily injure the tympanic membrane (For long procedures or ICU).

- The core-skin temperature gradient is a useful guide for CO as if the gradient increases above the normal range 3-4°C, it indicates a low CO.

- If a heating apparatus is used, the skin temperature adjacent to it should be closely monitored and gradients > 10°C must be avoided to avoid burning.

8. Invasive ABP and AB gases:

- Use a **preductal artery** e.g. right radial artery. So, PaO₂ can reflect PaO₂ delivered to **the retina or the brain** in presence of patent ductus arteriosus especially if retinopathy of the newborn is a problem. So, avoid postductal arteries e.g. left radial artery, umbilical artery, and posterior tibial arteries.

Induction:

It is either i.v., inhalational, i.m., or rectal induction:see before 'The Practice Conduct of Anesthesia'.

Airway Management:**1. Face Mask:**

- **Rendell-Backer – Soucek mask** is designed specifically to decrease the dead space as any increase in the dead space can cause greater effects than in adults.
- Clear face masks are preferred to black ones.

- On holding the mask, avoid pressing upward on the tongue below the mandible to avoid occlusion of airway by pushing the tongue against the posterior pharyngeal wall, the chin should be supported by pressure on the mandible alone.

2. Breathing System:

a. Ayres T-piece Apparatus (Mapleson E):

- Fresh gas flow:

For spontaneous ventilation = $2-2.5 \times$ minute ventilation.

For controlled ventilation = 7 mL/kg/min for PaCO₂ 40 mm Hg.

= 10 mL/Kg/min for PaCO₂ 30 mm Hg (Minimum 3 L/min)

- Advantage:

- Decreases dead space to a minimum.
- Low resistance to expiration (due to absence of valves).
- It can be used for spontaneous ventilation, but only for short periods in very young children as even a small increase in the dead space causes unacceptable levels of rebreathing.

b. Jackson Rees Modification of Ayre's T-piece (Mapleson F):

- By addition of an open-ended reservoir bag.
- Fresh gas flow: as Mapleson E.
- Advantages: Allows controlled ventilation manually or by attaching a ventilator to the expiratory limb.

c. Bain, Murphrey ADE or Small Disposable Closed Circuits:

- They can be used for older children. They decrease fresh gas flow and air pollution.

3- Tracheal Intubation:

- It may be difficult due to anatomical changes see before.....

- Laryngoscope:

In infants, it is better to use a **straight blade (Miller)** laryngoscope due to the large floppy U-shaped epiglottis where it is introduced till the epiglottis. The epiglottis is elevated from its under-surface by the blade but, this may cause **vagal stimulation** because the under-surface of the epiglottis is supplied by a vagus nerve.

- Miller size 1 for infants > 2500 grams.
- Miller size zero for smaller infants.

- Endotracheal tubes:

• Internal diameter (mm):

- General formula = $\text{Age} / 4 + 4$
- E.T.T. 0.5 mm larger or smaller than the predicted should be readily available.
- Correct size is confirmed by;
 - Easy passage into the larynx.
 - Development of a **gas leak at 15-25 cm H₂O** pressure. If there is no leak, it is an oversized tube which may cause postoperative edema. If an excessive leak occurs, it is an undersized tube which may cause decreased ventilation and increased pollution.

N.B.; French size: It is the external circumference in mm
 $= \pi \times \text{external diameter} (\pi = 3.1416 = 22/7)$
 $= 18 + \text{Age}$
 $= \text{ID (mm)} \times 4 + 2$

Weight or age	Internal diameter (mm)	Length (cm) to mid-trachea
1 Kg	2.5 Uncuffed	7
1.5 Kg	3.0 Uncuffed	7.5
2 Kg	3.0 Uncuffed	8
3 Kg (Preterm)	3.0 Uncuffed	9
3 Kg (Term)	3.0 Uncuffed	10
6-12 month	3.5 Uncuffed	11
12-18 month	3.5 Uncuffed	12
18-36 month	4.0 Uncuffed	13
3-5 year	4.5 Uncuffed	14
5-6 year	5.0 Cuffed	15
6-8 year	5.5 Cuffed	16
8-10 year	6.0 Cuffed	18
10-12 year	6.5 Cuffed	18

• Length (cm):

- General formula = $\text{Age} / 2 + 12$
- The correct length is confirmed by;

FLASHLIGHTS ON ANESTHESIA

- Advancing the tube 1-2 cm just beyond the infant's epiglottis (indicated by the black mark at the end of some tubes).
- **Auscultating** the chest until equality occurs.
- **Cuff: Uncuffed tubes** are used for children < 5 years old because;
 - Cuffs may impringe on the cricoid cartilage (the narrowest part of infant airway) causing **postoperative edema**, stridor, croup and airway obstruction.
 - To provide a leak to **decrease the risk of accidental barotrauma**.
- **Securing the tube:** with adhesive tape secured to the maxilla and the upper lip (and not the mandible and lower lip) which are extremely mobile in small children (except if it is not feasible e.g. cleft lip and palate).

4- Laryngeal Mask Airway:

- It is used for short procedures and day cases.
- Size: see before 'Airway management'
- Advantage: It decreases the risk of post-extubation spasm, stridor and edema.
- Disadvantages:
 1. It is not appropriate for controlled ventilation in children due to;
 - Relatively short esophagus.
 - Possibility of inappropriate positioning.
 Both can cause gaseous distension of the stomach increasing regurgitation.
 2. It is not appropriate for children at risk of aspiration.

Maintenance:

- Anesthetic agents: See before in pharmacologic changes.....
- **Controlled ventilation: is needed in infants** due to;
 - 1- Difficulty in maintaining the airway during surgery with a mask.
 - 2- The reduction in the cross-sectional area of the airway caused by 3.5 – 4.0 mm tubes in small infants increases the **resistance** approximately 16 times, compared with the 3 times increase in adults with 9.5 mm E.T.T.
- Muscle relaxants are reversed by:
 - Anticholinestrases e.g. neostigmine up to 70 µg/Kg.
 - Anticholinergics e.g. atropine 0.02 mg/Kg.
- Intraoperative fluid therapy.....as above.
- Intraoperative temperature maintenanceas above.

Emergence and Recovery:

Postoperative Complications include:

	1- Post-Intubation (Post-Extubation) Croup	2- Laryngospasm
Pathology	It is glottic or tracheal edema especially at the cricoid cartilage (as it is the narrowest part of the pediatric airway).	It is forceful, involuntary spasm of the laryngeal muscles.
Cause and precipitating factors	<ul style="list-style-type: none"> • Early childhood (1-4 years) especially in ill-patients. • Repeated intubation attempts. • Cuffed tubes or large tube sizes allowing no air leak at 15-25 cm H₂O pressure. • Prolonged surgery. • Excessive tube movement e.g. coughing, head and neck surgery. • Co-existing upper respiratory tract infection. 	Stimulation of the superior laryngeal nerve due to; <ul style="list-style-type: none"> • Extubation during light anesthesia. It can be avoided by extubation during either: - Fully awake (i.e. eye opening). Or - Fully anesthetized (i.e. no cough). • Active upper respiratory tract infection. • Intubation increases the incidence of bronchospasm, but has the same incidence of laryngospasm when compared with the LMA. • Environmental tobacco smoke.
Time of occurrence	Late postoperatively as it appears usually within 3 hours up to 8 hours of extubation (the time for occurrence of edema). So, it is better to avoid	Immediate postoperatively , but it may occur in the recovery room as the patient wakes up and chokes on pharyngeal secretions. So, the recovery

	intubation in day case patients.	of pediatric patients should be in the lateral position allowing pooling and draining of oral secretions away from the cords to the out-side.
Treatment	<p>1- Increase FiO_2 to 0.5-0.6, humidified</p> <p>2- Drugs:</p> <ul style="list-style-type: none"> • Dexamethazone i.v. 0.1-0.2 mg/kg • Aerosolized epinephrine via a hand-held nebulizer and mask. It is either: <ul style="list-style-type: none"> - Racemic epinephrine: (2.25% diluted in 5 mL saline). Dose: 0.05 mL/Kg delivered in 10 min - Aqueous epinephrine: (0.1% diluted in 5 mL saline). Dose: 0.5 mL/Kg delivered in 10 min <p>It can be repeated every 30 min if needed</p> <p>Rebound phenomenon can occur about 2 hours after cessation of therapy.</p> <p>3- If hypoxia persists;</p> <ul style="list-style-type: none"> • Re-intubate (tracheostomy may be needed). • Atropine. • 100% O_2. 	<p>1- 100% O_2 with gentle +ve pressure ventilation by bag and mask (manually) while doing jaw thrust and chin lift by firm pressure by the middle fingers of both hands in the laryngospasm notch (It lies behind the lobule of the pinna of each ear and is bound anteriorly by the ascending ramus of the mandible adjacent to the condyle, posteriorly by the mastoid process of the temporal bone, and cephalad by the base of the skull).</p> <p>2- Drugs:</p> <ul style="list-style-type: none"> • Lidocaine i.v. 1-1.5 mg/Kg. • Succinylcholine i.v. 0.25 mg/kg to produce vocal cord paralysis then controlled ventilation is done (+ atropine). <p>3- If hypoxia persists;</p> <ul style="list-style-type: none"> • Re-intubate. • Atropine. • 100% O_2.

3- Postoperative Pain:

Analgesics are prescribed as a routine except for neonates and small infants.

1. NSAIDS:

- E.g. Ketorolac (oral, i.m. and rectal).

2. COX -2 Inhibitors:

- E.g. Pediatric COX-2 inhibitor is **Nimesulide** (Other COX-2 inhibitors have not been tried yet in pediatrics as celecoxib 'Celebrex' or rofecoxib 'Vioxx').

- They provide analgesia as NSAIDs **without gastritis or bleeding** (but there is no decrease in the risk of nephropathy).

3. Paracetamol: Oral (up to 10 mg/kg) or rectal (40 mg/kg) for mild pain.

4. Systemic Opioids: either by:

- I.m. for older children for severe pain.

- I.v. infusion for older infants (i.e. > 1-2 months of age) and children.

They are **not used** for term and preterm neonates (< 1 month) as they cause apnea in non-intubated neonates.

5. Patient Controlled Analgesia, Nurse Controlled Analgesia or Parent Controlled Analgesia: (with nurse observation).

6. Epidural or Caudal Blockade:

a- LA infusion alone.

b- Opioid infusion alone.

c- LAs and Opioids:

N.B.; Addition of clonidine causes prolonged analgesia. It does not produce itching, ileus, nausea or urinary retention. It is an antiemetic.

Addition of ketamine has the same effects as clonidine.

Special Pediatric Anesthetic Management

Prematurity

Definition: A neonate who is delivered before 38 weeks gestational age.

Anesthetic Management:

Anesthetic Problems:

- 1- C.V.S.: - C.V.S. changes in pediatrics.
 - Patent ductus arteriosus (PDA).
- 2- Respiratory system: - Respiratory changes in pediatrics (than adult)
 - Respiratory distress Syndrome (RDS) = Hyaline membrane disease.
 - Apnea spells.
- 3- C.N.S.: - Intracranial hemorrhage.
 - Kernicterus.
- 4- Retinopathy of prematurity (ROP) (Retrolental fibroplasias)
- 5- Other problems:

<ul style="list-style-type: none"> - Hypoglycemia. - Ischemic gut and necrotizing enterocolitis. - Increased incidence of hypothermia. - Difficult venous access. 	<ul style="list-style-type: none"> - Hypocalcemia. - Increased incidence of congenital anomalies. - Immaturity of kidney and liver - Difficult airway control. 	<ul style="list-style-type: none"> - Sepsis.
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Preoperative Management:

Preoperative assessment and management for common medical diseases which can occur in full term babies are done, but their incidence and severity increase with the increase in degree of prematurity.

1- C.V.S.:

1. CVS Changes in Pediatrics: see before

These differences (than adult) make the neonate very sensitive to the depressant action of volatile agents.

2. Patent Ductus Arteriosus (PDA):

Incidence: It increases with prematurity.

Cause:

In term neonates, the ductus arteriosus closes soon after birth in response to the increased PaO₂, but in preterm neonates, PDA may occur due to;

- The **thinner, poorly contractile muscular layer** of the ductus with a decreased response to the increased O₂ levels after birth.
- Preterm neonates often suffer from **hypoxemia due to respiratory distress syndrome**.

I.e. there is **decreased stimulus and response to physiologic closure**.

Effects:

On the 3rd – 5th day of life, some resolution of the respiratory distress syndrome occurs which decreases the pulmonary vascular resistance. This allows blood shunting from the systemic to the pulmonary circulation by PDA producing pulmonary vascular overload (pulmonary congestion) which in turn produces;

- Left sided heart failure.
- Worsening of respiratory failure with further hypoxemia and CO₂ retention.
- Continuous or machinery murmur.

For diagnosis and treatment:see congenital heart diseases.

2- Respiratory System:

1. Respiratory Changes in Pediatrics (than adult)see before.

2. Respiratory Distress Syndrome (RDS) = Hyaline Membrane Disease.

Incidence: It increases with prematurity.

Cause:

Deficiency of surfactant in the alveoli increases the surface tension with **alveolar collapse**. This causes **right to left intrapulmonary shunting** leading to arterial hypoxemia and metabolic acidosis. This causes 50-75% of all deaths of premature infants.

N.B.; Surfactant is produced from type II pneumocytes at the 35th week of gestation although type II pneumocytes are present at 26 weeks of gestation, but they do not produce enough surfactant.

Treatment:

a. **For the mother:** Antenatal steroid administration to the mother may accelerate maturation of the lungs and prevent the development of RDS in preterm infants.

b. **For the neonate:**

1- **Oxygenation** to increase PaO₂.

- It is monitored by **preductal artery cannulation** for AB gases or pulse oximeter.

- It is given usually by mechanical ventilation ± PEEP or high frequency ventilation.

2. **Human surfactant** given via the tracheal route is limited, but gives promising results.

3. **Inositol.**

4. Maintain **Hct** of the preterm near **40%** to optimize O₂ delivery to the tissues.

5. Avoid excess hydration as this may re-open the ductus arteriosus.

3. Apnea Spells:

They are cessation of breathing that last **at least 20-30 seconds** and produces cyanosis and bradycardia.

Incidence: It increases with the increase in the degree of the prematurity.

20-30% of preterm infants show apnea spells during the 1st month of life **especially** premature infants < **50-60 weeks of conception i.e. post-conceptual age.**

N.B.; Gestational Age = Period of pregnancy.

Post-natal Age = Period after birth.

Post-conceptual Age = Gestational Age + Post-natal Age.

E.g. If there are 2 infants and their post-natal age is 20 weeks. The 1st infant is born at 25 weeks (gestational age) so, his post-conceptual age is 45 weeks. The 2nd infant is born at 40 weeks (gestational age) so, his post-conceptual age is 60 weeks. Therefore, the 1st infant is more liable to get apnea than the 2nd one although their post-natal age are the same.

During anesthesia, these infants who have apneic spells.

- Do not breathe during anesthesia so, they should be **ventilated**.

- Apnea spells can occur postoperatively in the first 24 hours so; these patients need **close postoperative observation with pulse oximeter and apnea alarm for the 1st 12-24 postoperative hours** especially those < 60 weeks conception (so, they are not suitable for out-patient anesthesia).

They can be prevented by i.v. caffeine or aminophylline.

N.B: Sudden Infant Death Syndrome (SIDS):

- Sudden death occurs between 1-12 months of age.

- Risk factors: • Premature infants. • Broncho-pulmonary dysplasia. • Infant apnea syndrome.

3- CNS:

1. Intracranial (IC) Hemorrhage:

2. Kernicterus:

Cause: due to the toxic effects of **unconjugated bilirubin** on the CNS (**bilirubin encephalopathy**) although normally bilirubin is not lipophilic and does not readily cross the BBB, but it can cross BBB in preterm infants.

FLASHLIGHTS ON ANESTHESIA**4- Retinopathy of Prematurity (ROP) (Retro-lental Fibroplasias)**Causes and Precipitating Factors:

1. The degree of **prematurity (and immaturity of the retinal vessels at birth)**.
2. **Hyperoxia:** It is unclear what the level of PaO_2 that causes ROP is, but:
 - Exposure to PaO_2 of 150 mm Hg for 1-2 hours can cause ROP.
 - Exposure to PaO_2 of 80-100 mm Hg for longer periods can cause ROP.

So, it is **recommended** to maintain PaO_2 **between 50-70 mm Hg**
(Or SaO_2 **between 87-92%** for infants < 44 weeks post-conceptual age and low birth weight by using mixture of O_2 and air or N_2O with monitoring by AB gases (from preductal artery) or even pulse oximeter.

3. Other factors:

- | | | |
|----------|--------------------------------------|--------------|
| * RDS. | * Hypoxia, hypercarbia and acidosis. | * Infection. |
| * Apnea. | * Bradycardia and heart diseases. | * Anemia. |

Treatment:

- Maintain O_2 level as above.
- Vitamin E for its antioxidant action, but its efficacy is unproven.

5- Other Problems:**1. Hypoglycemia:**

- Definition: - For preterm neonates s. glucose < 25 mg%
- For term neonates (< 3 days life) s. glucose < 35 mg%
- For term neonates (at 3 days life) s. glucose < 45 mg%
- For adults s. glucose < 50 mg%

2. Hypocalcemia:

- Definition: - Total s. calcium < 3.5 mEq/L.
- Ionized s. calcium (Ca^{++}) < 1.5 mEq/L.

Causes:

- Premature neonates are at a great risk of developing hypocalcemia because fetal Ca^{++} stores are largely achieved during the last trimester of pregnancy.

3. Sepsis.**4. Ischemic Gut and Necrotizing Enterocolitis.****5. Increased Incidence of Congenital Anomalies in Prematures.****6. Increased Incidence of Hypothermia.****7. Immaturity of the Kidney and Liver Decreases Drug Elimination.****8. Difficult Venous Access.****9. Difficult Airway Control.**

Congenital Diaphragmatic Hernia

Classification:

According to anatomic location of the defect (figure 27-1):

- Absent diaphragm: It is very rare.
- Eventration of the diaphragm: It is very rare.
- Diaphragmatic hernia:
 - Right (10%) or left (the most common 90%) postero-lateral foramen of Bochdalek 80%.
 - Anterior foramen of Morgagni 2%.
 - Para-esophageal 15-20%.

Pathophysiology:

During fetal development, herniation of the gut via the diaphragm (usually the left side) occurs causing;

1. **Pulmonary hypoplasia:** due to compression on the lung, retarding maturation of both lungs especially on the ipsilateral side with marked increased in the PVR.

2. **Atelectasis:** due to compression of the developed lung.

3. **Acidosis:**

• **Respiratory:** Due to atelectasis and pulmonary hypoplasia.

• **Metabolic:** due to lactic acidosis which occurs due to hypoxia and anaerobic glycolysis.

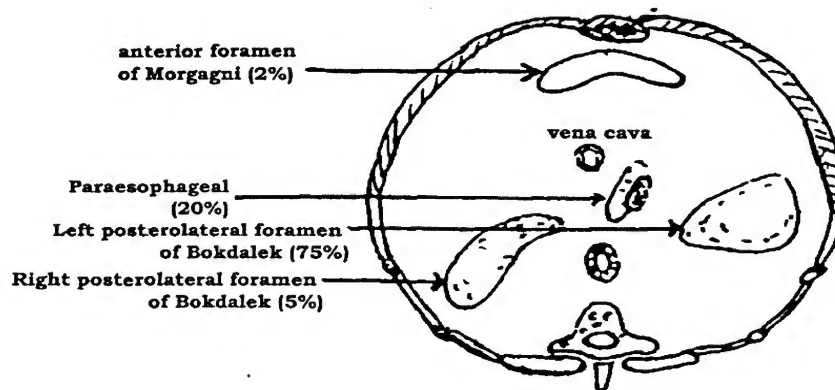


Figure 27-1; Congenital diaphragmatic hernia

4. **Persistent fetal circulation:** (hypoxia + hypercarbia + acidosis)

Atelectasis or pulmonary hypoplasia and markedly increased PVR increases the PA pressure which produces shunting of blood via the patent ductus arteriosus (PDA). This increases hypoxia causing a severe increase in the PVR and the PA pressure resulting in RVF. This increases RA pressure and when it exceeds left atrial pressure, shunting via the patent foramen ovale occurs causing more hypoxia which leads to LV failure. This in turn produces systemic hypotension with more shunting via the PDA resulting in more hypoxemia. So, a vicious cycle occurs unless the PA pressure is decreased. Therefore, progressive hypoxemia occurs causing death.

C/P:

• **Respiratory distress** causing cyanosis and hypoxia.

• **Scaphoid abdomen with barrel shaped chest.**

• **Auscultation** shows: Decreased breath sounds on one side.

Heart sounds are best heard on the right side (in left sided hernias).

• **Radiology** shows an evidence of **bowel in the thorax.**

• Associated **congenital anomalies** as ASD, VSD, hydrocephalus, spina bifida, GIT atresia and hypospadias may be present.

Anesthetic Management:

Preoperative Management:

1. Preoperative Assessment and Management of the C/P and Complications:

E.g. - Respiratory assessment.

- Dehydration, electrolyte and acid-base disturbances.

- CVS: LVF in late cases.

- Gastric decompression by naso-gastric tube.

FLASHLIGHTS ON ANESTHESIA**2. Preoperative Assessment of the Prognosis:****a. Assessment of the degree of pulmonary hypoplasia:**

- It is related to the time of the herniation of abdominal organs into the pleural cavity. The earlier the herniation, the more severe the pulmonary hypoplasia.

- As - Severe bilateral hypoplasia is associated with high mortality rates 80 %.
 - In unilateral hypoplasia, the patient may survive with aggressive treatment.
 - Insignificant hypoplasia is associated with low mortality rates 20% (excellent prognosis).

- By;

1. Alveolar-Arterial O_2 Tension Gradient (A-a) PO_2 :

With 100% O_2 ; If PA-a O_2 is > 500 mm Hg, this is predictive of **unsurvival**.

If PA-a O_2 is 400-500 mm Hg, **uncertain** prognosis is present.

If PA-a O_2 is < 400 mm Hg, this is predictive of **survival**.

2. Intra-pulmonary shunt Q_s/Q_t

3. Cardiac catheterization.

4. Pulmonary angiography.

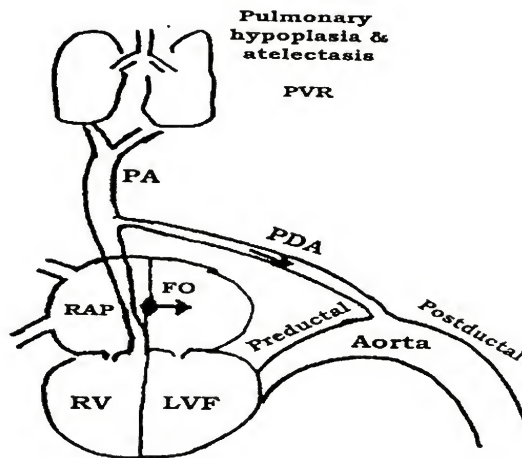


Figure 27-2; Persistence of fetal circulation in congenital diaphragmatic hernia

b. Diagnosis of persistent fetal circulation via ductus arteriosus and foramen ovale.

- Right to Left shunting of 20% is considered normal in newborn infants

- By;

1- Pre- and post-ductal PaO_2 :

- If shunting occurs via **ductus arteriosus**, preductal PO_2 is > postductal by 15-20 mm Hg.
- If shunting occurs via **foramen ovale**, preductal PO_2 is < that predicted for 20% shunting.
- If the preductal shunting is severe (as shunting through foramen ovale), detection of ductal shunting is impossible.

2. Cardiac catheterization.

3- Pulmonary angiography.

c. Presence of other congenital anomalies.

4. Premedication:

- Sedatives: are not needed.

- Atropine:

Intraoperative Management:

Monitoring: Standard +

- AB gases from a preductal artery e.g. right radial or temporal artery.

- C.V.P.
- Body temperature.

Induction:

- Preoxygenation.
- **Awake intubation** (often without a muscle relaxant).
- **Inhalational induction** (Halothane + 100% O₂) is used if the neonate is **too vigorous**.

Maintenance:

- If the patient is **shocked and severely hypoxic**:
100% O₂ + muscle relaxants e.g. pancuronium + CMV are given.
 - If the patient is **stable** (ABP)
O₂ (+ air) + muscle relaxants + Halothane or fentanyl + CMV are given.
- O₂: maintain PaO₂ between as prematurity.
 - N.B.; N₂O is avoided due to;
 - Hypoxemia.
 - Air expansion in the bowel causing; - Further compression on the lung.

Intraoperative Fluid Therapy:as above.

Intraoperative Body Temperature:as above.

Recovery and Extubation:

Extubation should occur only after fulfilling the criteria of extubation as normal AB gases, full consciousness, return of reflexes and good lung expansion.

If these criteria are not fulfilled, transfer the baby to the ICU intubated for CMV which is usually what happens.

Postoperative Management:

In ICU

The postoperative course is characterized by a **honeymoon period** of rapid improvement followed by **sudden deterioration** by profound arterial hypoxemia, hypercarbia, and acidosis due to the increased PVR causing a right to left shunt via the ductus arteriosus which may lead to death.

Therefore; **decreasing pulmonary hypertension is essential** by;

1. Maintaining **general anesthesia** by fentanyl 3 µg/Kg/hr + a muscle relaxant (pancuronium).
2. Decreasing endotracheal tube **suctioning** to avoid even transient hypoxia.
3. Maintaining **mechanical ventilation** with **hyperventilation** (i.e. decreased V_t and increased RR). This causes respiratory alkalosis (pH = 7.55-7.60) which causes pulmonary VD.
4. **High frequency oscillatory ventilation** which improves oxygenation and decreases barotrauma.
5. Moderate restriction of i.v. fluids (2-4 mL/Kg/hr).

6. Drugs which decrease the PVR:

- **Tolazoline** (a pulmonary vasodilator) 1 mg/kg followed by 5 mg/kg/hr.
- N.B.; Dopamine is given to decrease the systemic effects of tolazoline.
- Prostaglandins D₂, E₁, bradykinins and NO (NO is not shown to increase survival).

7. Extra-Corporeal Membrane Oxygenator (ECMO):

Indications:

Severe hypoxia and pulmonary hypertension not responding to the previous treatment.

Technique:

It involves pumping blood from the **right atrium** through a membrane **oxygenator** and counter current **heat exchanger** before returning it to either;

- The **ascending aorta** (Veno-arterial ECMO).

FLASHLIGHTS ON ANESTHESIA

Or - The femoral vein (Veno-veno ECMO).

Both systems provide a temporary method of oxygenation and ventilation in patients whose lungs can not tolerate conventional mechanical ventilation.

Advantages:

- It diverts 80% of CO from RA to the extracorporeal circuit immediately eliminates or decreases right to left shunt via foramen ovale and ductus arteriosus. Systemic oxygenation decreases ductal blood flow causing spontaneous closure of PDA.
- It decreases the RV work due to decreased pulmonary blood flow and PA pressure.
- It decreases pulmonary VC due to correction of hypoxia and acidosis.
- It allows rapid growth of the hypoplastic lung.
- It decreases the incidence of broncho-pulmonary dysplasia due to decreased FiO₂ and decreased airway pressure.

Contraindications:

- Patients < 35 weeks of gestation or weights < 2000 gm.
- Aggressive respiratory therapy for periods > 1 week or irreversible lung diseases.
- Congenital defects incompatible with good outcome e.g. congenital heart diseases.
- Pre-existing intracranial hemorrhage.

Complications:

- Intracranial hemorrhage.
- Pulmonary hemorrhage.

Tracheo-Esophageal Fistula

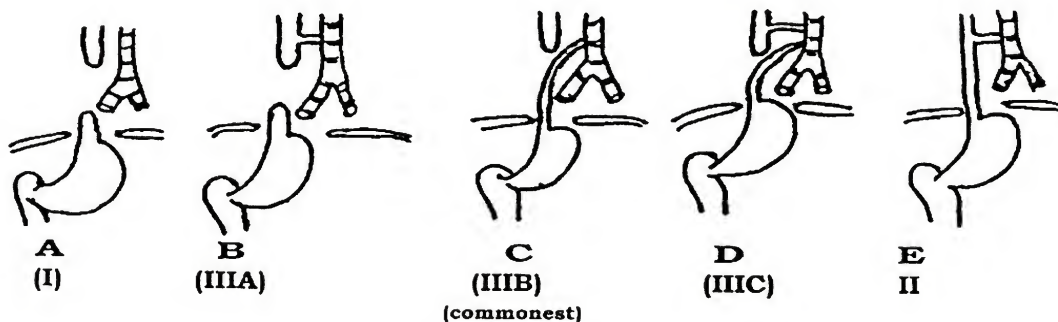
Types:

Figure 27-3; Trachea-esophageal Fistula

Gross and Vogt Classification:

- Type A: Esophageal atresia + no fistula.
- Type B: Esophageal atresia + fistula between the upper segment and the trachea.
- Type C: Esophageal atresia + fistula between the lower segment and the trachea (the commonest 87%).
- Type D: Esophageal atresia + 2 fistulas between the upper and the lower segment and the trachea.
- Type E: no atresia, but a fistula between the esophagus and the trachea.

Type H or N: are subtypes of E where tracheal opening is more cephalad than esophageal opening.

C/P:

1) Diagnosed by;

- Failure of passage of a catheter down to the stomach (except type E).

• On feeding, choking, cyanosis, and coughing occur (i.e. 3 Cs of esophageal atresia) causing aspiration pneumonia.

2) Dehydration.

3) Acid –base disorders:

• **Respiratory acidosis** due to pneumonia, shunting, hypoxia, hypercarbia, atelectasis, gastric distension with elevation of the diaphragm causing impaired diaphragmatic excursion so, the infant may need one lung ventilation until gastric decompression occurs.

• **Metabolic acidosis** due to severe dehydration and shock i.e. tissue under-perfusion.

4) **Associated congenital anomalies:**

As - **VATER:** Vascular or vertebral anomalies, Anal (or GIT) atresia, Tracheo-Esophageal fistula, and Renal or Radial anomalies.

- CVS: VSD, ASD, or F₄; they need echocardiography.

Anesthetic Management:

Preoperative Management:

1- Preoperative Assessment and Management of C/P and Complications:

E.g. - Pulmonary infection (with antibiotics).

- Dehydration.

- Acid base disturbances.

- Frequent suction of the upper esophageal pouch in the semi-sitting position.

2- Preoperative Assessment of Prognosis: By;

Risk classification according to Waterston and colleagues:

Group	Criteria	Management
Group A	Body weight > 2500 gm and well.	These infants could undergo total repair immediately.
Group B ₁	Body weight 1800-2500 gm and well.	These infants could safely undergo staged repair (i.e. gastrostomy 1 st).
Group B ₂	Body weight > 2500 gm and with moderate pneumonia and congenital heart diseases.	
Group C ₁	Body weight < 1800 gm.	Surgeries for these infants should be postponed.
Group C ₂	Body weight 1800-2500 gm and with severe pneumonia and congenital heart diseases.	

3- Gastrostomy: may be done in the pre-repair period under local anesthesia

Value: • It prevents gastric distension.

• It prevents reflux of the gastric content into the lungs.

• It allows proper nutrition of the baby in pre-or post-repair periods.

• It prevents elevation of the diaphragm so, avoiding respiratory distress.

Premedications:

- Sedatives: are avoided.

- Atropine: to avoid bradycardia.

Intraoperative Management:

Induction and Intubation:

- **Before intubation,** frequent suctioning of the upper esophageal pouch by a catheter introduced via the mouth as infants are obligate nasal breathers.

- **Induction:** as congenital diaphragmatic hernia.....

- **Endotracheal tube:** (without Murphy eye to block the fistula).

• **Size:** It should be large enough to - Allow easy suctioning.

FLASHLIGHTS ON ANESTHESIA

- Allow **blocking of the fistula** so preventing gastric distension on C.M.V.

• **Position:** It should be **above the carina and below the opening of the fistula** to allow blocking of the fistula by the tube. So, it is passed 1st into the right main bronchus then is withdrawn gradually until breath sounds are heard bilaterally equal. This position is confirmed by:

1. **Auscultation** of both lungs and the stomach.

2. **Fiberoptic bronchoscopy.**

N.B.; If the fistula is connected to the carina or a main stem bronchus, in this case, it is impossible to place the tube end distal to the opening of the fistula so, **intermittent venting of a gastrostomy tube** that has been placed preoperatively may allow +ve pressure ventilation without excessive gastric distention.

Maintenance:

O₂: Air (N₂O) + Halothane 1.5% + Spontaneous ventilation.

- O₂: Air (N₂O): - Maintain O₂ between..... to avoid.....

- If gastrostomy was done, O₂ can be diluted by N₂O (instead of air) according to the patient status.

- **Spontaneous ventilation (with halothane 1.5%)** is used **before doing the repair.**

Then **controlled ventilation** (with halothane 0.5% and muscle relaxants) is used **after doing the repair** because:

- Mediastinal stability is essential for proper repair.
- No fear of gastric distention is present now.

• Intraoperative fluid therapy.....

• Intraoperative body temperature.....

Monitoring: Standard +

• **AB gases:** It is taken from a **preductal artery.**

• **Invasive ABP and CVP:** according to the patient condition.

Extubation and Recovery:

- Before extubation, adequate suctioning from the ETT with 100% O₂ ventilation and tracheo-bronchial toilet is done.

- Fulfill criteria of extubation ... etc.

Postoperative Management: In ICU**Postoperative Complications:**

1- **Respiratory:** pneumothorax, atelectasis, and tracheomalacia. This needs CMV.

2- **Esophageal:** recurrence of fistula, esophageal stricture, and chronic gastro-esophageal reflux.

3. **Leaks** from the anastomotic line.

4. **S.C. or mediastinal emphysema.**

5. **Recurrent laryngeal nerve injury.**

Hypertrophic Pyloric Stenosis

C/P and Pathology:

It interferes with emptying of gastric contents causing **persistent vomiting** of ingested formula (no bile). This causes the loss of;

- K⁺ → Hypokalemia.
- Na⁺ → Hyponatremia (it is not manifested in the serum due to severe dehydration).
- Cl⁻ → Hypochloremia.
- H⁺ → Metabolic alkalosis
- H₂O → Dehydration.

- Hazards of **metabolic alkalosis**:

1. **Hypoventilation**: • It increases periods of **apnea** and the risk of atelectasis.
• It produces compensatory **respiratory acidosis**.
2. **Shift of the O₂-Hb dissociation curve to the left** decreasing O₂ delivery to tissues.
3. **Hypocalcemia** (i.e. decreased free ionized Ca⁺⁺) causing **tetany**.
4. Increased risk of **seizures**.

- Severe dehydration produces hypovolemia which in turn causes **circulatory shock** with inadequate tissue perfusion and impaired liver and renal functions. Therefore; **metabolic acidosis** occurs resulting in hyperventilation which produces compensatory respiratory alkalosis.

Anesthetic Management: Elective pyloro-myotomy is done.

Preoperative Management:

1. Preoperative Assessment and Management of C/P and Complications:

This may take **12-72 hours**, because it is not an emergency surgery e.g.

- **Dehydration**: It may be mild, moderate, or severe (see before). It is managed by D₅W in saline (or NS alone) + K⁺. Avoid lactated ringer's solution as lactate is metabolized to HCO₃⁻.
- **Electrolyte imbalance** as hypokalemia

2. Premedications:

- **Sedatives**: They are not needed to avoid loss of airway reflexes and aspiration.
- **Atropine**: -----

Intraoperative Management:

Intubation and Induction:

- **Before intubation, empty the stomach** by introduction of a wide bore **naso-gastric or oro-gastric** tube to avoid aspiration.
- **Induction**: as congenital diaphragmatic hernia.....
- + **Rapid sequence i.v. induction** with suxamethonium and cricoid pressure.

Maintenance:

O₂: N₂O (1:1) + Halothane + Muscle relaxants and CMV.

Postoperative Management: In ICU

Postoperative Complications:

1. **Respiratory depression and periods of apnea**:
due to: • Persistent metabolic alkalosis • Hypothermia.
2. **Hypoglycemia**.

Abdominal Wall Defects Gastroschisis and Omphalocele

They are congenital disorders characterized by defects in the abdominal wall.

	Gastroschisis	Omphalocele
• Location	• Lateral to the umbilicus (usually on the right).	• At the base of the umbilicus (within the umbilical cord).
• Hernial sac	• Absent so, more complications occur	• Present .
• Associated congenital anomalies	• None.	• 75% are associated with congenital anomalies e.g. congenital heart disease, trisomy 21, and congenital diaphragmatic hernia.

Anesthetic Management:**Preoperative Management:**

1- At birth, the abdominal contents should be covered by a **moist towel** and the infant should be placed in a **bowel bag (a silastic pouch)** to:

- Prevent **heat loss** + maintain ambient temperature at the neutral temperature.
- Prevent **fluid and electrolyte loss** + give i.v. fluids.
- Prevent **infection** + give prophylactic systemic antibiotics.

2. **Preoperative assessment and management of complications:**

- **Hypothermia.**
- **Dehydration** which needs i.v fluids (25% at least colloids) = 6-12 mL/Kg/hr.
Electrolyte and acid base disturbances as acidosis.
- **Hypoglycemia.**
- **Infection:** systemic antibiotics.

Empty stomach by a naso-gastric tube.

Intraoperative Management:

Monitoring: Standard +

- **Invasive ABP.**
- **AB gases.**
- **Airway pressure monitoring** for detecting changes in the pulmonary compliance which can occur during **tight closure of the abdomen.**

Induction and Intubation: As congenital diaphragmatic hernia.....

Maintenance:

O₂: Air + volatile agents + muscle relaxants and C.V.

- O₂: Air: N₂O is avoided to prevent bowel distention and allow easy return of the bowel inside the abdomen.

- **Muscle relaxants:**

They are needed to allow replacement of the bowel into the abdominal cavity.

- **Intraoperative fluid therapy:** 3rd space fluid losses are **aggressively replaced**

- **Intraoperative body temperature**.....

Postoperative Management: In ICU

The neonate usually remains intubated with CMV for the 1st 1-2 postoperative days.

Upper Airway Diseases and Obstruction

Causes: (4 groups)

1. Chronic Airway Obstruction:

- Congenital anomalies as; laryngomalecia, hemangioma, or hypoplastic mandible.

2. Progressive Airway Obstruction:

- Infections of airway as epiglottitis, croup, diphtheria, or peri-tonsillar abscess.
- Laryngeal papillomas treated by laser.....see ENT.

3. Sudden Airway Obstruction:

- FB aspiration.
- Airway trauma.

4. Difficult Intubation:

Without known congenital or acquired causes.

Q: Child With Difficult Airway, discuss?

Q: Emergencies of airway in children, discuss?**A:** • Anatomical differences of airway than adult.

- Causes as above..... + Post-tonsillectomy bleeding.
- C/P of airway obstruction.
- Intubation: inhalation, awake, fiberoptic, rigidetc.
- Premedications: atropine to decrease secretions and sedatives are avoided.
- Postoperative complications: Hypoxia and hypercarbia may cause arrhythmia, sudden airway obstruction and post-intubation croup.

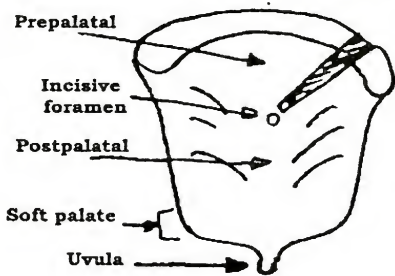

Craniofacial Abnormalities

It includes:

- 1) Cleft lip and palate.
- 2) Mandibular hypoplasia.
- 3) Hypertelorism: Increased distance between the eyes.

1. Cleft Lip and Palate

Types:**a. Cleft Lip:** bilateral or unilateral, complete or incomplete.**b. Cleft Palate:**

	Pre-Palatal Cleft	Post-Palatal Cleft
		
Site	Anterior to the incisive foramen.	Posterior to the incisive foramen.
It includes	Anterior palate, alveolus, lip, nostril floor and ala nasi.	Posterior palate, soft palate and uvula.
It is either;	Complete or incomplete.	Complete or incomplete depending on extension through the way between the soft and hard palate to the incisive foramen.
	Left complete pre-palatal cleft is the 1 st most common type.	Midline cleft of all the soft palate and part of the hard palate (without reaching the pre-palatal area) is the 2 nd most common type.

N.B.; Embryology:

- Three mesodermal islands (one central and 2 lateral) which fail to fuse causing pre-palatal cleft.
- Palatal ridges fail to migrate medially and fuse from anterior to posterior causing post-palatal cleft (figure 27-4).



Figure 27-4; Embryology of the palate

Anesthetic Management:**Preoperative Management:****1. Preoperative Assessment and Management of C/P:**

- **Feeding problems:** There is **failure to thrive**, and **anemia** (it should be treated preoperatively to be ≥ 10 gm %).
- **Chocking and aspiration:** cause repeated upper respiratory tract infections and chronic middle ear infections.
- **Speech problems** (in older children): as **hyper-nasality** (i.e. increased nasal tone).
- **Psychological problems:** especially at school age.

2. Preoperative assessment for other associated congenital anomalies.**4. Premedications:**

- Sedatives: not needed.
- Atropine.....
- Antibiotics.....

Intraoperative Management:**Induction and Intubation:**

- According to the presence of **airway obstruction**.
- 1. If there is **no airway obstruction** e.g. by other anomaly, **i.v.** induction and intubation is recommended.
- 2. If there is **airway obstruction** e.g. by other anomaly, **inhalational** intubation is recommended.
- If muscle relaxants are required for intubation, **assess the facial configuration** of the patient to assess if it allows effective controlled mask **ventilation** or not.
- Laryngoscopy is done with care to avoid falling into the cleft and causing trauma so, insertion of a small piece of gauze or dental roll to fill the gap may be needed.
- **E.T.T:**
 - The **preformed RAE tubes** are of choice to curve away from the field.
 - **Non-kinkable tubes** to avoid occlusion by the palate retractor.
 - The **tube is fixed to the lower lip** in the midline to avoid distortion of the facial anatomy.
 - The tube is held under the tongue blade of the mouth gag, care should be taken to avoid be advancement into the main bronchus or dislodgement from the trachea. Breath sounds should be monitored when the gag is opened. If any change occurs, the gag should be closed and the tube repositioned until the breath sounds are normal with the gag fully opened (also ET CO₂ is important).
- **Pharyngeal pack:** to protect against food or blood aspiration.
- **Eye cover:** is important.
- **Lidocaine** (maximal dose 5 mg/kg) + **epinephrine** (maximal dose 10 µg/Kg) can be used for infiltration.

Maintenance:

O₂: Air (N₂O) + Halothane + muscle relaxants + CMV.

Extubation and Recovery:

- **Awake extubation** in the lateral position is done after good suction under vision and removal of the pack.
- **Avoid the use of oral or nasal airways** as they may disrupt the surgical sutures.
- **Traction sutures** may be placed through the **middle of the tongue** and taped to the cheek, in cases of postoperative airway obstruction, the tongue be pulled forward with the suture to open the airway. It is removed when the infant leaves the recovery room.

Postoperative Management:

In ICU for 24 hours at least.

Postoperative Complications:

1. Hemorrhage.
2. Respiratory obstruction so keep patients in the semi-sitting position with the head extended to one side.
3. Hypothermia.
4. Breakdown of the sutures.
5. Scarring.
6. Infection.

Anesthetic Problems of Craniofacial Surgery:**1. Difficult Tracheal Intubation Versus Elective Tracheostomy.**

It needs proper preoperative assessment and preparation.

2. Problems due to Face Surgery.

- Possibility of **tube kink** (needing an armored tube) or **tube displacement** (needing proper fixation and observation) or **disconnection** (needing an alarm).
- Possibility of **corneal abrasion** especially if with proptosis (needing eye protection).

3. Problems due to Lengthy Surgery (may be up to 18 hours).

- Intraoperative **hypothermia** so...
- Intraoperative **fluid** management so....
- **Pressure necrosis and nerve injury** so needing careful positioning and padding.

4. Excessive Blood Loss so,

- Elevate head up by 15-20°C.
- Invasive monitoring.
- Large venous access.
- Preoperative blood preparation.

5. Intracranial hypertension so it is treated by ...

6. Postoperative Mechanical Ventilation of the lungs for several days as the entire head may be wrapped in pressure dressings through which only the ETT protrudes.

CNS Diseases

1. Trisomy -21 (Down Syndrome)

Due to presence of an extra (trisomy) 21 chromosome.

Anesthetic Problems (and C/P):**1. Difficult Airway Management:**

- Difficult laryngoscopy due to asymptomatic **atlanto-axial instability** that needs lateral neck X-ray screening.
- Difficult intubation due to **short neck, irregular dentition, narrow nasopharynx large tongue adenoid and tonsils or sub-glottic stenosis** (that needs smaller E.T.T).

2. Mongolism: flat facies with oblique palpebral fissure.

Single palmer crease (simian crease) to confirm the diagnosis.

3. Congenital heart diseases in 40% e.g. VSD, ASD, F4, or PDA.**4. Congenital duodenal atresia or tracheo-esophageal fistula.****5. Mental retardation and seizures.**

6. Chronic pulmonary infections and chronic upper airway obstruction causing chronic hypoxemia which leads to **polycythemia**.

7. Hypotonia.

8. Obesity: more difficult venous cannulation is present.

FLASHLIGHTS ON ANESTHESIA**2. Craniostenosis (Cranio-Synostosis)**

Due to premature closure of one or more cranial suture (the commonest is the sagittal suture). It causes deformity of the skull needing craniectomy.

Anesthetic Problems:

- 1) Exophthalmos and optic atrophy.
- 2) Increased ICP and hydrocephalus.
- 3) Seizures.
- 4) Mental retardation.
- 5) Congenital heart disease.

Separation of Conjoined Twins**Anesthetic Problems:**

1. Preoperative preparation and discussion among surgeons, pediatricians and anesthetist.
2. Preoperative assessment of the **shared organ systems**;
E.g.; • Joining from the head is called **cranio-pagus**.
 - Joining from the thorax is called **thoraco-pagus**.
 - Joining from the upper abdomen is called **xipho-pagus**.
 - Joining from the lower abdomen is called **omphalo-pagus**.
 - Joining from the pelvis is called **ischio-pagus**.
 - Joining from the sacrum is called **pyo-pagus**.
3. **Two teams and separate anesthetic machines, monitors ventilators ... etc even 2nd OR table.**
4. **Invasive monitoring** is usually needed.
5. Presence of a **cross-circulation** means that the drugs given to one infant are likely to produce detectable effects on the other, it varies from minute to minute resulting in **difficult prediction of drug effects**.
6. **Other associated congenital anomalies** should be assessed.

Sedation and Analgesia Procedure Outside the OR (in Pediatric Patients)**Definition of Sedation:**

By American Society of Anesthesiologists (ASA) and joint Commission on Accreditation of Health Care Organization (JCAHO).

They divided sedation into 4 levels:

Level	Minimal Sedation (Anxiolysis)	Moderate Sedation/Analgesia (Conscious sedation)	Deep Sedation/Analgesia	General Anesthesia
Response	- Responds normally to verbal commands	Responds purposefully to verbal commands alone or with light touch	- Responds purposefully to repeated or painful stimuli i.e. cannot easily be aroused (reflex withdrawal is not considered a purposeful response)	- No response by reflex withdrawal
Airway	- Airway and ventilation are maintained	- Airway and ventilatory pattern are maintained.	- Airway may be/ may be not maintained.	- Airway is lost

CVS	- CVS function is maintained.	- CVS function is maintained.	- CVS function is usually maintained.	- CVS function may be impaired.
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Indications:

- 1- In the emergency departments e.g. fractures and lacerations.
- 2- Diagnostic imaging areas e.g. CT scan, MRI, and barium studies.
- 3- GIT: Endoscopy.
- 4- Pulmonary: Bronchoscopy.
- 5- CVS: Echocardiography and catheterization.
- 6- Burn unit: Dressings.
- 7- In other areas: e.g. chest tube removal, bone marrow aspirations....etc.

Sedation Techniques:

• **The place** where conscious sedation is done should be equipped with the resuscitative drugs and equipment.

• The same doses of **drugs** as before....see premedications.

1- Fentanyl: Oralet, i.v.

2- Ketamine: Oral, i.m., i.v., nasal, and rectal routes.

3- Midazolam: Oral, i.m., i.v., nasal, and rectal routes.

4- Diazepam: Oral, i.m., or i.v.

5- Chloral hydrate: Oral and rectal routes.

6- Propofol: • Patient controlled sedation (minimal sedation) using boluses of 25-50 $\mu\text{g/Kg}$.

• Continuous infusion 50-200 $\mu\text{g/Kg/min}$ i.v.

7- Nitrous Oxide: It is used only in concentrations < 50%.

• **Adjuvant techniques** used with sedation:

1- **Psychologic support** to allay anxiety (cuddling, parent support, warm blankets, and gentle reassuring voice and hypnosis).

2- **Local Anesthesia:** The analgesia produced can decrease the requirements of systemic sedatives and narcotics e.g. any regional or local techniques including Bier block, EMLA cream, ELA-Max cream, TAC cream.....etc.

N.B.; Sedation and analgesic procedures outside the OR (in adult patients) are the same as that in pediatric patients.

Q: Discuss conscious sedation?

Q: Discuss office based anesthesia?

CHAPTER 28

ANESTHESIA FOR FETAL SURGERY

Fetal Physiology

A) Fetal Circulation:

- The placenta, which receives nearly 1/2 the CO of the fetus is responsible for respiratory gas exchange. As a result, the lungs receive little blood flow and the pulmonary and systemic circulations are parallel instead of in series, as in adults (figure 28-1).
- This arrangement is made possible by 2 cardiac shunts:
 - The foramen ovale.
 - The ductus arteriosus.

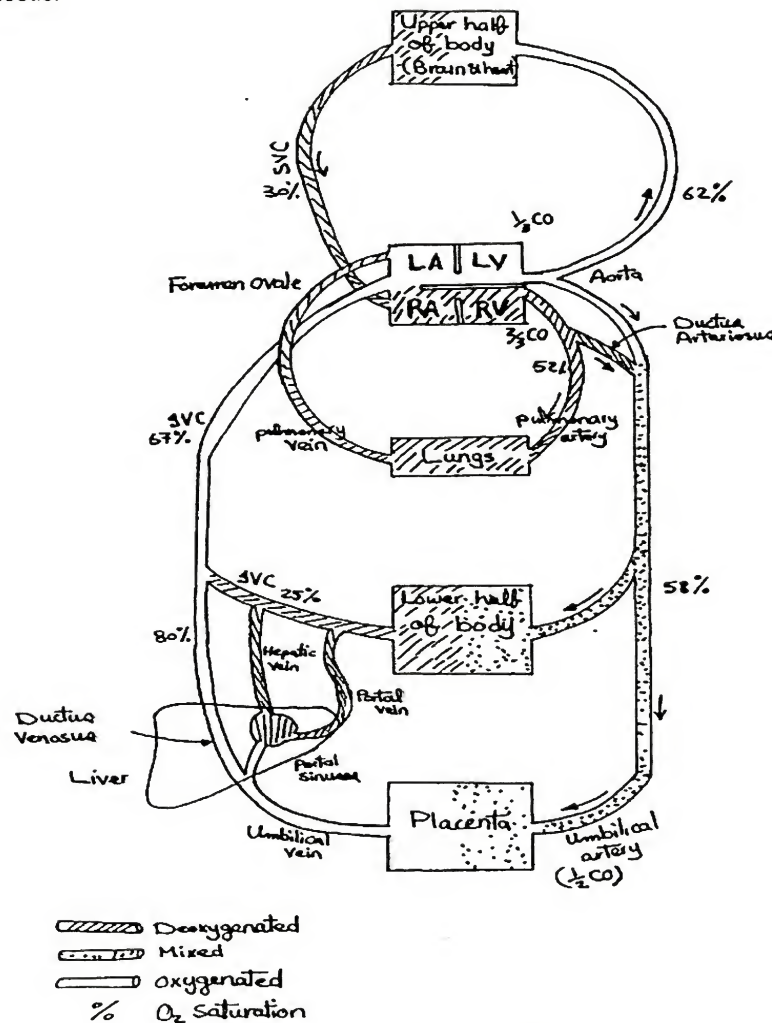


Figure 28-1; Fetal Circulation

- Well-oxygenated blood from the placenta (80% SaO_2) mixes with venous blood returning from the lower body (25% SaO_2) and flows via the inferior vena cava into the right atrium.

ANESTHESIA FOR FETAL SURGERY

- Up to 1/2 of the well-oxygenated blood in the umbilical vein can pass directly to the heart via the ductus venosus, bypassing the liver. The remainder of the blood flow from the placenta mixes with blood from the portal vein (via the portal sinus) and passes through the liver before reaching the heart. The latter may be important in allowing relatively rapid hepatic degradation of drugs (or toxins) absorbed from the maternal circulation.
- Right atrial anatomy preferentially directs the main stream of blood flow from the inferior vena cava (67% SaO₂) through the foramen ovale into the left atrium.
- Left atrial blood is then pumped by the left ventricle to the upper body (mainly the brain and the heart) (62% SaO₂).
- Poorly oxygenated blood (30% SaO₂) from the upper body returns via the superior vena cava to the right atrium.
- Right atrium anatomy preferentially directs the low from the superior vena cava into the right ventricle.
- Because of high pulmonary vascular resistance 95% of the blood ejected from the right ventricle is shunted across the ductus arteriosus into the descending aorta, and back to the placenta (with low systemic vascular resistance) and lower body.
- Pulmonary vascular resistance is high (high pressure low flow circuit) due to;
- Large arteriolar muscle mass causing great vasomotor response.
- Pulmonary blood flow is less sensitive to neuronal (as less autonomic nerve endings) and endocrinal stimuli.
- The parallel circulation has unequal ventricular flows;
- The right ventricle ejects 2/3 of the combined ventricular outputs (66%).
- The left ventricle ejects 1/3 of the combined ventricle outputs (34%).

B) Fetal Lung:

- In contrast to the fetal circulation, which is established very early during intra-uterine life, maturation of the lungs lags behind.
- Extra-uterine life is not possible until after 24-26 weeks of gestation, when pulmonary capillaries are formed and come to lie in close approximation to an immature alveolar epithelium.
- At 30 weeks, the cuboidal alveolar epithelium flattens out and begins to produce pulmonary surfactant. This substance provides alveolar stability and is necessary to maintain normal lung expansion after birth. Sufficient pulmonary surfactant is usually present after 34-38 weeks of gestation. Administration of corticosteroids to the mother can accelerate fetal surfactant production.

Evaluation of the Fetus:

1. Measurement of maternal plasma and urinary **estriol** excretion and plasma **placental lactogen** concentrations.
2. **Amniotic fluid analysis:**
 - By abdominal amniocentesis, to assess fetal lung maturity before elective C.S. or induction of labor especially in diabetic mothers.

By determining $\frac{\text{Lecithin}}{\text{Sphingomyelin}}$ ratio by chromatography.

If it is > 2-3.5, this indicates fetal lung maturity due to increased lecithin concentration in the amniotic fluid which ensures adequate pulmonary surfactant activity. This usually occurs at 35 weeks of gestation.

3- Ultrasonography:

- To measure fetal bi-parietal diameter which is related to the fetal age.
- Also, it is important to detect hydramnios, hydrocephaly, anencephaly and fetal spine anomalies.

Fetal Distress

Causes:

1. Causes of decreased UBF.....see before.
2. Decreased O₂ passage from the mother to the fetus via;
 - a. Maternal; hemoglobinopathy or anemia.
 - b. Placental; infarction or premature separation.

c. Cord; prolapse or knotting of the cord.

Diagnosis: By Fetal Monitoring

A. Fetal Heart Rate Monitoring:

It is recorded by using - External monitor (Doppler).

- Fetal scalp electrode.

1. Base Line Heart Rate:

HR at term normally = 120 – 160 /min.

2. Base Line (Beat to Beat) Variability:

- Normally, there is a baseline beat to beat variability (from R wave to R wave). This variability is normally from 2-6 (up to 20 in some cases) beats/min.

3. Deceleration Patterns: It is a relation of fetal HR to uterine contractions.

Type	Definition and value	Cause	
Early (type I) Decelerations	<ul style="list-style-type: none"> - The decreased fetal HR is of early onset occurring with the onset of uterine contractions. Their peaks coincide with the peaks of uterine contractions and they are of uniform shapes (i.e. a mirror image of the uterine contractions). - Fetal HR is decreased by about 10-20 beat/min (Fetal HR does not decrease below 100 beat/min). 	Vagal response to compression of the fetal head or stretching of the neck during uterine contractions (It is not due to fetal distress). N.B.; It is not abolished by increasing fetal oxygenation or by atropine.	
Late (Type II) Decelerations	<ul style="list-style-type: none"> - The decreased fetal HR is of late onset after the onset of uterine contractions. Their peaks occur after the peaks of uterine contractions and is of a uniform shape. 	Fetal distress (Fetal hypoxia) due to decreased utero-placental blood flow N.B.; It is improved (abolished) by increasing fetal oxygenation, changing the maternal position, i.v. fluids, stopping uterine contractions by stopping oxytocin infusion otherwise, delivery is needed.	
Variable (type III) Deceleration The most common	<ul style="list-style-type: none"> - It is variable in onset, duration and peak in relation to uterine contractions. - Fetal HR changes by about > 30 beat/min and fetal HR is usually < 100 beat/min. 	Umbilical cord compression N.B.; Increased Fetal O ₂ has no effect, but atropine decreases this pattern.	

B. Fetal Blood Sampling: by small scalp puncture.

It is indicted when an abnormal fetal HR pattern persists.

pH > 7.20 indicates a vigorous neonate.

pH < 7.20 usually indicates neonatal depression.

ANESTHESIA FOR FETAL SURGERY**Treatment of Fetal Distress:**

1. Treatment of the cause: e.g.: Treat maternal hypotension e.g. i.v. ephedrine or fluids. Changing maternal position. Adjusting oxytocin infusion.
2. O₂ Supplementation.
3. Persistent evidence of fetal distress necessitates immediate delivery.

Anesthesia for Fetal Surgery

Fetal surgery includes:

Surgical approach.	Fetal lesion/anomaly
1) Open Fetal Surgery via hysterotomy	<ul style="list-style-type: none"> • Congenital diaphragmatic hernia. • Congenital cystic adenomatoid mal-formation. • Myelo-meningocele. • Sacro-coccygeal teratoma.
2) Ex Utero Intra-partum Therapy (EXIT) via hysterotomy	<ul style="list-style-type: none"> • Congenital or Iatrogenic high airway obstruction. • Giant fetal neck mass.
3) Feto-scopic Surgery via percutaneous placement of small trocars and laparoscopes into the uterus.	<ul style="list-style-type: none"> • Twin-twin transfusion or twin reversed arterial perfusion sequence (where umbilical cord ligation or selective ablation of fetal connecting vessels is done). • Bladder outlet obstruction (where feto-scopic laser ablation of the posterior urethral valves is done)

- A team consisting of surgeons, anesthesiologists, obstetricians, and genetic doctors should discuss the plan of surgery.
- Fetal surgery involves the simultaneous anesthetic management for both the fetus and the mother.

General Anesthetic Problems:**I) Maternal Anesthetic Problems:**

- Discuss the **physiologic changes of pregnancy** (as in obstetric anesthesia.....).

II) Fetal Anesthetic Problems:

- Nearly the same changes of the premature baby.

III) Utero-Placental Anesthetic Problems:

See before in obstetric anesthesia +

- a- Although **volatile agents decrease myometrial tone** (so help UBF), they also tend to **decrease maternal ABP** so, maternal ABP should be maintained within 10% of the baseline.
- b- There is **possibility of premature labor** so;
 - **Volatile-based anesthesia is essential** to decrease the myometrial tone (epidural anesthesia provides no uterine relaxation although it may help prevent premature labor in the postoperative period as it produces postoperative analgesia).
 - **Tocolytics** are used in some cases.

CHAPTER 29

ANESTHESIA FOR

GERIATRIC PATIENTS

Chronological Age (Age in Years):

An increase of the chronological age leads to unavoidable **structural changes** e.g. stiffness of blood vessels resulting in physiologic changes. Some authors consider ages of > 65 years as geriatric.

Biological Age (Medical Fitness):

- It is the **net effect** of chronological age + concurrent diseases e.g. DM, coronary artery diseases.
- It is more important than the chronological age in predicting the effect of anesthesia and postoperative morbidity and mortality.

Physiologic Changes: (All functions are decreased with increased stiffness)

1. C.V.S.:

1- **There is decreased arterial elasticity** due to changes in the media leading to increased **systolic BP** resulting in **LV hypertrophy**. There is a decreased or unchanged diastolic BP and a decreased CO with age.

Also, **pulmonary hypertension** occurs **increasing** the incidence of abnormal PCWP.

2- **Fibrosis of the conduction system** and loss of SA node cells increase the incidence of **arrhythmias**.

3- **Slow circulation time** delays the onset of i.v. drugs, but speeds the onset of volatile agents.

4- **Adrenergic receptors (and autonomic reflexes):**

- **β receptors of the heart:** there is a decreased ability of the heart to increase the HR and CO in response to exercise, hypovolemia, hypotension, and hypoxia (like infants) due to a **decreased response to catecholamines**.

- There is; • A decreased resting heart rate.

- A decreased maximal heart rate (one beat/min/year of age > 50 years).

- A decreased baroreceptor reflex.

- There is a decreased cardiac reserve which leads to exaggerated drops in ABP during induction of GA.

2. Respiratory System:

1- **Decreased lung elasticity** which causes;

- Over distension of alveoli which in turn causes decreased alveolar surface area.

- Decreased lung compliance.

- Collapse of small airways which in turn increases the residual volume and closing capacity.

N.B.; Closing capacity exceeds FRC at the age of 45 years in the supine position and at the age of 65 years in the sitting position.

All these changes produce ventilation/perfusion mismatching which in turn decreases gas exchange and causes hypoxemia (PaO₂ decreases 0.35 mm Hg/year).

2- **Increased chest wall rigidity.**

3- **Decreased muscle strength** which decreases cough, and maximal breathing capacity.

4- **Blunted response to hypoxia and hypercapnia.**

ANESTHESIA FOR GERIATRIC PATIENTS

5- Progressive decrease in protective **laryngeal reflexes** with age increasing the risk of aspiration.

6- Airway management:

- There is difficulty in **mask ventilation** especially in **edentulous patients**. So, some anesthetists allow the patient to wear dentures in the O.R. as this may facilitate mask ventilation, but absence of the upper teeth may improve vocal cord visualization by laryngoscopy.
- There is difficulty in **tracheal intubation** due to arthritis of the temporo-mandibular joint or the cervical spine.

3. CNS: (physiology of brain aging)

a- Biologic Changes:

- 1- **Decreased brain mass** and weight especially of the cerebral cortex due to **neuronal loss**. Also there is **decreased neuronal function** e.g. decreased neuronal size, complexity of the dendritic tree, and number of synapses. All these decrease the **MAC**.
- 2- **Decreased global CBF** 10-20% due to decreased brain mass, but there is a normal CBF per unit of weight, but there is normal autoregulation and normal response to CO₂ and O₂.
- 3- **Degeneration of peripheral nerve cells** which decreases **LA requirements**.
- 4- **Vertebro-basilar insufficiency** can be evaluated by determining the effect of extension and rotation of the head on the mental status.

5- **Disturbed sleep pattern.**

b- Cognitive Changes: Decreased cognitive function: as

- **Dementia** either 1ry or 2ry (disease related) e.g. alcoholism or Alzheimer disease.
- **Slowed reaction time** and cognitive processing.
- **Impaired short term memory** in 30-50% of elderly.
- **Impaired fluid intelligence** (i.e. the ability to dynamically evaluate, accommodate and respond to events), but stable crystallized intelligence (i.e. accumulated knowledge).

4. Renal:

- 1- **Decreased renal mass** especially renal cortex.
- 2- **Decreased renal blood flow** which leading to decreased renal plasma flow, and **GFR** (i.e. decreased creatinine clearance).
- 3- **Decreased tubular function** - **Impaired Na⁺ handling**.
 - **Impaired fluid handling.**
 - **Decreased diluting and concentrating capacity.**
 - **Decreased drug excretion.**
- 4- **Decreased renin-aldosterone responsiveness** causing impaired K⁺ excretion.
- 5- **Increased BUN** 0.2 mg/dL/year.

S. creatinine is unchanged although renal function is decreased due to the accompanied decreased muscle mass.

5. Liver and GIT:

- 1- **Decreased hepatic mass.**
- 2- **Decreased hepatic blood flow.**
- 3- **Decreased rate of biotransformation.**
- 4- **Decreased albumin synthesis.**
- 5- **Decreased plasma cholinesterase synthesis.**
- 6- **Increased gastric pH** and prolonged gastric emptying.

6. Musculo-Skeletal:

- 1- **Skin atrophies** with age and is prone to trauma from adhesive tape, electrocautery pads and ECG electrodes.
- 2- **Veins** are often **frail** and easily ruptured by i.v. infusions.

3- Arthritic joints produce **difficult positioning** (e.g. lithotomy), **regional anesthesia or intubation**.

7. Hypothermia:

It is more common due to decreased s.c. fat and decreased metabolic rate.

N.B.: Similarities Between Elderly and Infants:

- 1- Decreased ability to increase HR in response to hypovolemia, hypotension or hypoxia.
- 2- Decreased lung compliance which produce decreased PaO₂.
- 3- Decreased ability to cough.
- 4- Decreased renal tubular function.
- 5- Increased susceptibility to hypothermia.

Pharmacologic Changes:

1. Change in Volume of Distribution of Drugs:

Due to - Decreased total body water.

- Increased total body fat (doubling).

So; the volume of distribution is;

- Decreased for water soluble drugs causing higher plasma concentrations and decreased elimination $t_{1/2}$.
- Increased for lipid soluble drugs causing lower plasma concentrations and increased elimination $t_{1/2}$ (except when the clearance rate is increased).

2. Change in Plasma Protein Binding:

As - **Decreased albumin synthesis** (which binds acidic drugs e.g. barbiturates, opioids, benzodiazepines) increases their action.

- **Increased α_1 acid glycoprotein** (which binds basic drugs e.g. local anesthetics and muscle relaxants) decreases their action.

3. Decreased Renal Function decreases excretion of drugs which are renal dependent.

Decreased Hepatic Function decreases excretion of drugs which are hepatic dependent.

Therefore,

A. Inhalational Anesthetics:

- **MAC** is decreased 4% per decade of age > 40 years e.g. MAC of halothane in 80 years patients = $0.77 - (0.77 \times 4\% \times 4) = 0.65$.
- The onset of action is more rapid if CO is depressed.

Or more delayed if significant V/Q mismatching is present.

- The recovery is delayed due to increased volume of distribution (lipid soluble drugs).
- Exaggeration of myocardial depressant effects while the tachycardia of isoflurane and enflurane is attenuated (i.e. in contrast to young patients, isoflurane decreases CO and HR in elderly patients).

B. Non-Volatile Anesthetics:

- Dose requirements of barbiturates, opioids and benzodiazepines are decreased.

C. Muscle Relaxants:

- Depolarizing muscle relaxants:

Suxamethonium has a prolonged action in elderly men (not women) due to decreased plasma cholinesterases.

- Non-depolarizing muscle relaxants:

- Pancuronium and tubocurarine have a prolonged action as they depend on renal excretion which is decreased.

- Rocuronium and vecuronium have a prolonged action as they depend on hepatic metabolism which is decreased.

- Atracurium is not changed.

ANESTHESIA FOR GERIATRIC PATIENTS**D. Local Anesthetics:**

- Their requirements are decreased.
- Administration of a given volume of LA to:
 - **Epidural block produces more extensive cephalad spread (more hypotension)** but with a **shorter duration** due to progressive occlusion of intervertebral foramina with connective tissue so that little amounts of the drug escape which increases the spread and so, increases the surface area of absorption causing a shorter duration of action.
 - **Subarachnoid block produces more extensive cephalad spread (more hypotension), but with a longer duration** due to decreased vascular absorption due to atherosclerosis and decreased vessels surrounding the subarachnoid space.

Coexisting Diseases with Aging

- 1- **CVS:** Essential hypertension, ischemic heart diseases, atherosclerosis, CHF, and conduction disturbances.
- 2- **Respiratory:** COPD, pneumonia, carcinoma, and sleep apnea syndrome (apnea > 10 sec during sleep causing hypoxia).
- 3- **CNS:** Alzheimer's disease, postoperative cognitive dysfunction, and strokes.
- 4- **Renal:** Nephropathy (obstructive as enlarged prostate, diabetic, and hypertensive).
- 5- **Musculoskeletal:** Rheumatoid arthritis and osteoarthritis.
- 6- **Endocrine:** DM, and sub-clinical hypothyroidism.

The anesthetic management of the above diseases are discussed in details
 see corresponding chapters.

CHAPTER 30

LAPAROSCOPY (PERITONEOSCOPY)

Advantages of Laparoscopy:

- 1-The **cosmetic** results of small and non-muscle-splitting incisions.
 - 2-Less **blood** loss.
 - 3-Less postoperative periods of **hospitalization** and convalescence.
- So, an ultimately lower cost due to;
- Less postoperative **pain**.
 - Less postoperative **ileus**.
 - Less postoperative **pulmonary deterioration**, as pulmonary functions return to normal faster than in open surgeries especially in upper abdominal procedures e.g. laparoscopic Cholecystectomy and gastroplasty.
 - Less postoperative **wound infections and dehiscence**.

Disadvantages of Laparoscopy:

- 1-It needs **well trained** surgeons.
- 2-The **narrow**, two-dimensional visual **field** on video.
- 3-The need for **general anesthesia**.
- 4-Often of **longer duration** than open surgeries.
- 5-Although the **costs** are sometimes higher (especially with disposable instruments), they are recaptured by shorter hospitalization periods.

Contraindications:

Most contraindications are relative with experienced hand.

a- Related to **difficulty of the surgical technique:**

- Diaphragmatic hernia.
 - History of extensive surgery or adhesions.
 - Large intra-abdominal masses.
 - Tumor of the abdominal wall.
 - Morbid obesity.
 - Peritonitis.
 - Coagulopathies.
 - Surgeon inexperience (is the **strongest** contraindication).
- #### b- Related to **difficulty of the anesthetic techniques:**
- Severe cardiovascular or pulmonary diseases (including bullae).
 - Increased ICP or space occupying lesions.
 - Impending renal shutdown.
 - Sick cell disease (because acidosis may precipitate sickle crisis).
 - Hypovolemic shock.

c- **Patient refusal.**

Advantages of CO₂ as an Insufflating Gas

- 1- It is **non-flammable** and does not support combustion.
- 2- It readily diffuses through membranes and so, is **rapidly removed by lungs** and its elimination can be increased by increasing ventilation.
- 3- It is **highly soluble** so, the risk of CO₂ embolization is minimal.

ANESTHESIA FOR LAPAROSCOPIC SURGERY

As much as 200 mL of CO₂ injected directly into a peripheral vein may not be lethal, where as only 20 mL of air can be lethal.

4- CO₂ levels in blood and expired air can be easily measured.

5- As long as O₂ requirements are met, a high CO₂ concentration of blood can be tolerated.

6- Medical CO₂ gas is readily available and inexpensive.

Anesthetic Problems of Laparoscopy:

Especially in • Prolonged surgeries. • Old sick patients.

A- Problems of the Trendelenburg Position: (Head down tilt) in pelvic surgeries.

1- Respiratory Effects:

- Abdominal contents press on the diaphragm causing
 - Decreased compliance of the lungs which increases airway pressure.
 - Decreased vital capacity and FRC.
 - Increased endobronchial intubation due to elevation of the carina upwards. So frequent assessment of E.T.T. position is needed.

N.B.; This is accentuated by the effect of intra-abdominal pressure.

2- Cardiovascular Effects: (As with the lithotomy position)

- Leg elevation increases the venous return acutely (adds 600 mL blood to the central circulation). This precipitates or exacerbates congestive heart failure in compromised hearts.

- Also, rapid leg lowering decreases venous return acutely resulting in hypotension and decreased CO, especially with general anesthesia or regional anesthesia.

So; ABP monitoring is essential and body position must be changed gradually.

3- Pressure on the Stomach:

- It increases the intra-gastric pressure which increases the risk of regurgitation and aspiration.

4- Arm Abduction:

- It pulls on the brachial plexus (+ the effect of the shoulder brace) resulting in brachial plexus palsy.

5- Prolonged Position Resulting in Venous Congestion and Edema:

- Head and neck congestion so they become dusky.
- Conjunctival and eyelid edema.
- Retinal hemorrhage and detachment with increased IOP.
- Cerebral edema with increased ICP.
- Laryngeal, tongue and airway edema.

They are accentuated by the effect of intra-abdominal pressure.

B- Effects of Pneumo-Peritoneum or Increased Intra-Abdominal Pressure:

Especially if the intra-abdominal pressure exceeds 15- 20 mm Hg. So; avoid increasing the intra-abdominal pressure above this level.

1- **Pressure on the Diaphragm**as above with trendelenburg position.

2- **Pressure on the Stomach**as above with trendelenburg position.

3- C.V.S. Effects:

- An increased intra-abdominal pressure up to 15-20 mm Hg increases CVP, ABP, and CO due to compensatory mechanism.

- But further increases > 15-20 mm Hg produces pressure on the IVC which decreases the VR which in turn decreases the CVP, ABP, and CO.

4- Renal Effects: (especially > 15-20 mm Hg)

- It decreases renal cortical blood flow up to 60 % which in turn decreases UOP 50 %.

5- GIT Effects: (especially > 15-20 mm Hg)

- It decreases perfusion of the bowel leading to bowel hypoxia.
- It causes residual stretching of the peritoneum which increases postoperative nausea and vomiting.

6- Pneumothorax and Pneumo-mediastinum: (rare)**- Causes:**

1. Increased lung pressure (barotrauma) especially if emphysematous bullae are present.
2. Passage of gas into the pleural cavity or pericardial spaces through;
 - Anatomical or congenital defects in the diaphragm (as hiatus around the esophagus) (Embryologically, before formation of the diaphragm, the peritoneal and pleural cavities are derived from one sac).
 - Acquired defects in the diaphragm.

7- Rapid Stretching of the Peritoneum:

- It causes stimulation of the vagal reflexes leading to bronchospasm and bradycardia up to sinus arrest especially in young women.

So; - **Avoid increased gas flow rates > 6 L/ min.**

- Be ready with vagolytic drugs (may be given prophylactically).

C- Effects of CO₂ (as Insufflating Gas)**1- Direct Peritoneal Irritation:**

It causes pain during laparoscopy under local anesthesia.

It causes postoperative pain referred to the shoulders.

- 2- If a large CO₂ volume is insufflated intravascularly inadvertently, It leads to **gas embolism** which may lead to acute pulmonary embolism.

C/P:

- It is suspected when the abdominal cavity does not distend equally in all four quadrants despite insufflation of several liters of CO₂.
- There is decreased ABP, increased HR and Mill-wheel murmur which is heard by an esophageal or precordial stethoscope so, it is better used.
- Ventilation/perfusion mismatching causes hypoxia, cyanosis and a sudden fall of EtCO₂.
- The most sensitive means are the precordial and trans-esophageal Doppler, and trans-esophageal echocardiography.

So, - Close monitoring during insufflation is important as early detection decreases morbidity and mortality.

Treatment: (When it is suspected, it is managed as air embolism).

- 1- **Warn the surgeon** immediately to stop insufflation.

- 2- **Discontinue N₂O** to provide 100% O₂.

N.B.; Although N₂O expands air embolism volume, it does not expand CO₂ embolism volume because both N₂O and CO₂ are highly soluble. So, as N₂O enters the embolus, CO₂ leaves it.

- 3- Turn the patient to the **left lateral trendelenburg position** to trap the gas in the right side of the heart. So, avoiding obstruction of pulmonary tracts to avoid right ventricular failure.

- 4- **C.V.P catheter** can help in diagnosis and aspiration of emboli.

- 5- Supportive therapy as O₂, fluids, and vasopressors etc.

3- Hypercarbia (and Respiratory Acidosis):

It occurs due to increased CO₂ absorption. When the buffering capacity of blood is temporarily exceeded, respiratory acidosis occurs.

ANESTHESIA FOR LAPAROSCOPIC SURGERY**a- C.V.S. Effects: (+) → (-)**

• **Hypercarbia up to 90 mm Hg** produces **sympathetic stimulation** which increases myocardial contractility, ABP, HR, and CO. Also, coronary and cerebral VD occur (the later increases cerebral edema) and VC of pulmonary and capacitant vessels occur, but SVR is decreased.

• **Hypercarbia more than 90 mm Hg** produces a drop in the response.

N.B.; Block of sympathetic system e.g. by subarachnoid block, ganglion blockers or β blockers causes hypotension and decreases CO (instead of sympathetic stimulation) in response to hypercarbia.

• Hypercarbia increases **arrhythmias**. So, avoid the use of halothane.

b- Respiratory Effects: (+) → (-)

It is apparent in spontaneously breathing patients as with regional anesthesia.

• **Increased CO₂ up to 100-150 mm Hg** (and acidosis) produce direct and indirect **stimulation of the respiratory center** via chemoreceptors, hormones, and autonomic nerves resulting in hyperventilation.

• **Increased CO₂ > 150 mm Hg** produces respiratory depression.

• CO₂ alone causes bronchodilatation.

c- CNS Effects: (-) → (+) → (-)

• A slight increase in CO₂ produces direct cortical depression (and increases the threshold for seizures).

• **Further increases in CO₂** stimulate sub-cortical and hypothalamic centers leading to indirect cortical stimulation (and it decreases the threshold for seizures).

• **Further increases in CO₂** inhibit sub-cortical and cortical centers (anesthetic like state).

• CO₂ (and not H⁺ ions) crosses the BBB decreasing the CSF pH which produces cerebral VD. So, CBF increases which increases ICP and causes cerebral edema. These effects are accentuated by:

- Venous congestion due to the trendelenburg position.
- Increased intra-abdominal pressure.

d- Renal Effects: (-)

• Hypercarbia produces sympathetic stimulation which;

- Increases ADH secretion.
- Decreases renal cortical blood flow.
- Produces VC of glomerular afferent arterioles.

All these decrease GFR leading to oliguria. This is accentuated by the effect of intra-abdominal pressure.

4- Increased CO₂ Diffusion Inside the Bowel Leading to Bowel Distension.

This; • Increases postoperative nausea and vomiting (than open surgery).

• But decreases postoperative ileus.

5- Hypothermia:

Due to insufflation of dry cold gas (CO₂), body temperature decreases by 0.3 °C/hr.

So, take measures to avoid hypothermia as temperature monitoring, warming and humidifying inspired gas, warming of i.v. fluid and heating mattress or radiant heaters etc.

D- Surgical Faults:

Inadvertent gas insufflation or injury of viscera necessitates open surgery.

E- Day Case:

It may be considered as a day case anesthesia so, take its precautions.....see later

Q: What are the respiratory effects (causes of hypoxia) during laparoscopy?

What are the C.V.S. effects (causes of hypotension) during laparoscopy?

Anesthetic Techniques:

Preoperative Management:

Although the case is a minimally invasive technique, it should be considered as a major surgery because it may turn to laparotomy at any time.

- 1- Complete history, examination, and investigations are taken as it is a major case.
 - 2- The patient's consent for laparotomy should be ready.
 - 3- Complete bowel preparation is necessary as bowel injury may occur.
 - 4- Anti-embolic compression stocking is applied.
 - 5- Two large bore i.v. cannulas should be placed due to the risk of major hemorrhage.
 - 6- A naso- or oro-gastric tube is inserted (usually after anesthesia) to decompress the stomach, decreasing the risk of regurgitation and stomach injury.
- It should be intermittently suctioned during the operation because CO₂ gas continues to diffuse into the stomach and distend it.

- 7- A urinary Foley's catheter is inserted.

To: - Decompress the urinary bladder so, decreasing the risk of its perforation.

- Observe urine color to detect bladder injury.

- Observe urine volume to detect oliguria and adjust the fluids given.

- 8- Premedications:

- Anti-emetics e.g. ondansetron or dolasetron (5-HT₃ receptor antagonists).
- Antacids and H₂ antagonists to decrease aspiration effects.
- S.c. heparin to decrease the risk of D.V.T.
- Anticholinergics may be given.

Intraoperative Management::

Patient Monitoring:

Standard +

- Clinical observation especially for - Congestion of head, neck, upper chest and eyes.
- S.c. emphysema

- Peak airway pressure: It gradually increases during insufflation.

- Temperature monitoring.

- Esophageal or precordial stethoscope for heart murmurs of pulmonary embolism.

- **Capnography:**

- During laparoscopy, CO₂ absorption increases markedly so, PaCO₂ levels increase and Et-CO₂ increases at first rapidly then a plateau occurs between 15-35 minutes despite continuing low flow insufflation. This is due to the increased storage of CO₂ in tissues. If ventilation remains constant, CO₂ levels increase further with an increase in Et-CO₂, but if ventilation increases (i.e. hyperventilation), PaCO₂ level are kept constant and Et-CO₂ reaches a plateau again.

Patient Position:

- 1- Trendelenburg position (head down):

With: - Lateral rotation, for urological procedures.

- Dorso-lithotomy, for gynecological procedures.

- 2- Anti-trendelenburg position (head up)

For upper GIT and biliary tract surgeries, but venous stasis in lower limbs increase the risk of DVT.

- 3- Lateral decubitus:

For thoracoscopy, nephrectomy or adrenalectomy.

Intraoperative Fluid Management:

Patients require less fluids during laparoscopies to avoid pulmonary edema especially in older patients due to:

ANESTHESIA FOR LAPAROSCOPIC SURGERY

- 1- Third space loss is much less than in open surgeries.
- 2- No fluid loss is caused by evaporation.
- 3- The volume of retained intra-peritoneal saline (= volume of irrigation fluid – volume of suctioned fluid) should be added to the final total volume infused.
- 4- Decreased UOP (which is not related to volume depletion).

Choice of Anesthesia:**A- General Anesthesia:**

- It is the most commonly used technique and is of choice because:
 - 1- The duration may be long.
 - 2- Patients may be anxious.
 - 3- Trendelenburg position, increased intra-abdominal pressure, and CO₂ affect respiration more severely in spontaneous breathing patients.
 - 4- There is a difficulty to insert naso-or orogastric tube in conscious patients.
 - 5- Good muscle relaxation is needed because:
 - It allows a better surgical field.
 - It allows the control of ventilation and so, can compensate for hypercarbia and respiratory acidosis.
 - It avoids patient's coughing during the procedure because coughing;
 - Increases positive pressure of the thorax resulting in increased risk of pneumothorax and gas passage.
 - Increases intra-abdominal pressure further resulting in an increased risk of organ injury.
 - Produces movement of organs resulting in increased risk of organ injury.
- By Intubation + Volatile agents + N₂O + Opioids + Controlled ventilation.
- Intubation: Cuffed E.T.T. is essential.
- Volatile agents: **Avoid halothane** as it increases arrhythmias with hypercarbia.
- N₂O: its use is controversial because;
 - 1- N₂O may distend air containing bowel so, it increases the risk of bowel injury. But actually CO₂ has the same solubility of N₂O. So, it can also distend the bowel.
 - 2- N₂O may increase postoperative nausea and vomiting, But studies show that absence of N₂O does not decrease the incidence of postoperative nausea and vomiting.
- Medium duration opioids.
- Medium or short duration muscle relaxants for controlled ventilation.

B- Regional or Local Anesthesia:

- It is rarely used and has the following **disadvantages**:
 - 1- It requires a **high level of sensory block**, in spite of this, pain is still present (intra-peritoneally and referred to the shoulders) (due to the irritant effect of CO₂ on the peritoneum). So, N₂O can be used instead of CO₂ as an insufflating gas.
 - 2- Rapid distention and traction on the peritoneum causes **nausea**.
 - 3- Block of the sympathetic system so, hypercarbia causes hypotension and depressed CO.
 - 4- **Hyperventilation** (due to hypercarbia) may cause **too much movement** in the surgical field.
 - 5- Opposite to advantages of GA (1-5)

Intraoperative Complications:.....see above anesthetic problems.

Postoperative Management:

Postoperative complications:

- 1- There is an increased incidence of postoperative **nausea and vomiting** (the incidence is 42%). It is the most common cause of overnight admission after day case surgery.

- 2- There is increased incidence of postoperative **pain** (referred to shoulders). It is better treated by NSAIDs. Avoid opioids as they increase nausea, vomiting and ileus.
- 3- There is increased incidence of **D.V.T.**
- 4- **Respiratory distress** may occur if pneumothorax is not detected intraoperatively.
- 5- Late complications (after several days or weeks) (not related to anesthesia).
 - Bowel obstruction and injury by:
 - Cautery burns.
 - Adhesions.
 - Omental or bowel herniation via the trocar site.
 - Peritonitis and septicemia.

Inter-Compartmental Syndrome **(Abdominal Compartment Syndrome)**

It is increased intra-abdominal pressure which exceed 15-20 mmHg causing harmful effects

Causes; - Intra-abdominal hemorrhage, laparoscopic insufflation, distension.

Investigation; intra-abdominal pressure is measured by manometer inserted in Foley's catheter.

a- Direct Measurement of IAP:

- By an intra-peritoneal catheter connected to a pressure transducer.
- This method is used during laparoscopic surgery and also for research work.

b- Indirect Measurement of IAP:

- By a urinary bladder catheter (Foley's catheter) connected to a pressure transducer.
- C/P;as aboveeffect of pneumo-peritoneum

CHAPTER 31**AMBULATORY**
ANESTHESIA**(DAY-CASE OR OUT-PATIENT ANESTHESIA)**

Day Case Anesthesia: It is anesthesia given to a day-case patient who is admitted for an investigation or operation on a planned non-resident bases.

Advantages:

- 1) It is more economic.
- 2) It allows earlier ambulation of the patient.
- 3) It decreases the risk of noso-comial infections especially in pediatric patients and immuno-suppressed patients.
- 4) It produces more patient convenience.

Anesthetic Management:**Preoperative Management:****A) Surgical Case Selection:**

Depends on;

1) The Resources of the Facility in the Day Case Unit:

E.g.: Day-case units may not allow complex operations due to lack of more comprehensive laboratory resources or greater access to specialized consultants.

2) The Estimated Duration of the Procedure:

Day case surgery is allowed for procedures taking ≤ 30 min (in the past < 90 min).

3) The Possibility of Extensive Postoperative Care:

Due to • The of surgery itself so, it is not suitable for;

- Procedures producing severe hemorrhage.
- Procedures producing severe postoperative pain.

- Preexisting medical condition of the patient.

B) Patient Selection:

- **It is done by preoperative visit, telephone interview/ no visit, review of health care questionnaire / no visit or internet.** All are usually done by the anesthetist.

- Preoperative Patient Evaluation includes:

- History by preoperative screening questionnaire.
- Physical examination.
- Routine laboratory tests and other relevant investigations only when indicated (see practical conduct of anesthesia).

- Patient Selection depends on:**1) Patient' State of Health:**

- Classically, ASA class I or II.
- Many centers currently allow ASA class III if they are medically stable.

So; these patients need to be evaluated on individual basis.

- Contraindications to Ambulatory Anesthesia:

- Unstable ASA III or IV.

- Patients susceptible to malignant hyperthermia (well educated patients may be treated as outpatients).
 - Patients with acute concurrent illness.
 - Morbid obese patients with systemic disease.
 - Acute drug abuse.
 - Patients on MAOIs (they should be discontinued at least 2 weeks prior to elective surgery).
 - Patients with upper respiratory tract infection (see pediatrics).
 - Patient's age (see below).
 - Patient's social circumstances (see below).
- 2) Age of the Patient: - Actually, age is not a contraindication to ambulatory anesthesia.
- Elderly: • An upper **age limit of 65-70 years** which should be judged on biologic rather than chronologic age.
 - But many authors consider that there is **no upper limit for age**.
 - Pediatrics: • They are suitable for day-case anesthesia except;
 - 1- **Premature infants** younger than **50 weeks post-conception**. Some centers use 44 weeks and others use 60 weeks as the cutoff limit.
 - 2- Infants with a **history of broncho-pulmonary dysplasia, ARDS or apnic spells** who have been symptomatic within the last 6 – 12 months.
 - 3- Siblings of infants who had died of **sudden infant death syndrome**.

These groups are at an increased risk of postoperative apnea and should be monitored for at least 24 hours after surgery so, they are not suitable for day-case anesthesia.
 - Both elderly patients and children benefit most from day-case surgery because they are more susceptible to the adverse psychologic effects associated with hospital admission.
- 3) Patient's Social Circumstances:
- The ability of the **patient** (or the **parent** of child) to **cooperate with written** preoperative and postoperative **instructions**.
 - The availability of a **responsible adult** to accompany the patient home and stay with him for 24 hours after the surgery.
 - The **facilities at home** e.g. presence of a telephone.
 - The **travel conditions**, as the use of public transport after GA is inappropriate.
- C) Patient Preparation:** (after patient's selection)
- 1) **Full explanation** to the patient about day-case anesthesia and the nature of the operation.
 - 2) Informed **consent** is signed.
 - 3) **Complete registration** is done with determination of the date of surgery.
 - 4) **Book any pathologic or radiologic investigations**.
 - 5) The patient should be given **written instructions in plain language** detailing
 - The date and time of attendance at the day-case unit.
 - Preoperative fasting (see pediatric anesthesia).
 - 6) Ask the patient to:
 - **Stop smoking** for 4 – 6 weeks before the surgery (if possible).
 - **Bring** with him all tablets and **medications that are taken regularly**.
 - 7) Patient's admission should allow **adequate time before surgery** for
 - History and examination.
 - Results of any investigations requested to be available and noted.
 - 8) Patients should receive an identify bracelet and their names should be entered into the nursing record.
 - 9) The **operative site** should be **marked**.

AMBULATORY ANESTHESIA**D) Premedications:**

- Most anesthesiologists do not routinely prescribe premedications for day-case surgeries.
- The **same considerations as in in-patients** are taken beside the goal of rapid emergence.
- **Types:** (See pediatric anesthesia for routes)
- **Sedatives:** temazepam, midazolam (**avoid long acting agents**).
- **Opioids:** only used if severe pain is anticipated as they may **increase the incidence of postoperative nausea and vomiting** prolonging the recovery time.
- **Anticholinergics:** antacids H₂ blockers and antiemetics can be used.

Intraoperative Management:

Monitoring: The same as in in-patients.

Choice of Anesthesia:**A) Regional Anesthesia:****Advantages:**

- 1) Less alteration in CNS functions (if no sedatives are given).
- 2) It provides postoperative pain relief.

Types:**1) Peripheral Nerve Blocks and Local Infiltration:**

- They are an excellent choice.
- ± Patient sedation by using short acting sedatives e.g. midazolam, propofol or remifentanyl.
- **Avoid techniques** that may be associated with **occult complications** e.g. pneumothorax after supra-clavicular approach of brachial plexus block as pneumothorax may become apparent after the patient's discharge.

2) Subarachnoid and Epidural Anesthesia:

- They can be used especially with low dose local anesthetics-opioid combinations.
- ± Patient sedation by using short acting sedatives e.g. midazolam, propofol or remifentanyl.
- They may cause complications that delay discharge e.g. orthostatic hypotension, prolonged motor or sensory block, urinary retention, and post-dural puncture headache (which is more common in out-patients than in in-patients).

B) General Anesthesia:**Induction:**

Short acting agents are the drugs of choice, but most induction agents can be used in day-case surgeries without interfering with the wake up time.

a) I.v. Agents:

- **Propofol is the drug of choice** due to;
 - The rapid easy, clear-headed, and euphoric recovery.
 - The low incidence of postoperative nausea and vomiting.
 - Oropharyngeal airways and laryngeal mask airways are accepted more readily after induction with propofol (as compared with other agents).
- Thiopentone, methohexitone and etomidate can be used.
- **Ketamine** is better **avoided** as it may prolong emergence in some patients.

b) Volatile Agents:

- **Sevoflurane is the drug of choice** because;
 - It has a lower blood/gas solubility coefficient than other agents leading to rapid induction and recovery.
 - It is not irritant to the respiratory tract (unlike desflurane).
- Halothane can be used.

Airway Management:

- **Short Procedures:** Face mask, laryngeal mask, or cuffed oropharyngeal airway (COPA).

- Long Procedures: Tracheal intubation can be used.

Maintenance:

- Either volatile based or TIVA can be used \pm N₂O or i.v. short acting opioids e.g. fentanyl, sufentanil or alfentanil..

a) Volatile Agents:

- **Sevoflurane and desflurane** are drugs of choice as they provide the **fastest recovery**....
- Halothane, isoflurane or enflurane can be used.

b) Total I.V. Anesthesia:

- Propofol infusion or remifentanyl infusion are drugs of choice.

- Muscle Relaxants:

a) Depolarizing muscle relaxants:

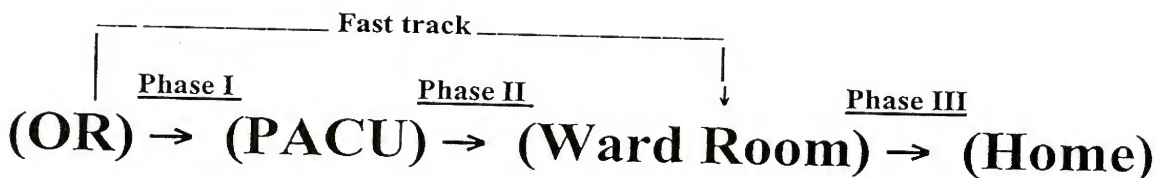
- **Suxamethonium** increases the risk of **muscle pains** especially in ambulant patients so, it is **better avoided** except for short procedures.

b) Non-depolarizing muscle relaxants:

- **Mivacurium is the drug of choice** as;
 - It has the **shortest duration of action**.
 - There is no need for neostigmine-glycopyrrolate reversal so, postoperative nausea and vomiting are decreased.
- Atracurium, vecuronium, and rocuronium are intermediate acting drugs and still can be used.
- Pipecuronium and pancuronium are long acting drugs so they are better avoided.

Postoperative Management:

A) Discharge Criteria:



I) Concept of Fast-Tracking for Ambulatory Patient Discharge:

- Patients usually pass 3 distinct, overlapping levels of recovery.
- **Phase I (Early Recovery):** in the post-anesthetic care unit (PACU).
- **Phase II (Intermediate Recovery):** in the step down area.
- **Phase III (Late Recovery):** at home.
- By the use of the newer anesthetics e.g. **propofol, remifentanyl, desflurane and sevoflurane**, the patient can be transferred directly from operating room after GA to the step-down unit (i.e. phase II recovery) without passing the PACU (i.e. bypass phase I recovery or PACU bypass). This is the **fast-tracking or Short Acting Fast Emergence (SAFE)**.

II) Criteria for Home Readiness:

- Many criteria and scoring systems are used in different centers.
- They usually include.
 - 1) **Orientation** to person, place, and time.
 - 2) **Stable vital signs** for 30-60 minutes (and no respiratory distress).
 - 3) Ability to **ambulate unassisted** e.g. walk in a straight line, sit unaided and standstill without swaying.
 - 4) Ability to **tolerate oral fluids** (not mandatory in all patients as it may induce vomiting).

AMBULATORY ANESTHESIA

5) **Ability to void** (not mandatory in all patients as some surgical manipulation can inhibit the micturition reflex).

6) **Absence of significant pain, bleeding, nausea or vomiting.**

These criteria assume normal preoperative functions.

- **Additional Criteria for Regional Anesthesia:**

- 1) Recovery of **proprioception** e.g. The patient can perceive big toe movement passively.
- 2) Recovery of **sympathetic tone** e.g. there is minimal orthostatic changes (hypotension or syncope on standing).
- 3) Recovery of the **bladder function** i.e. there is ability to void.
- 4) Recovery of the **motor strength** e.g. the patient can move his/her legs and feet freely or there is a normal planter flexion of feet.

A Simple Test: Patient's ability to walk to the bathroom and void.

- **Post-Discharge Instructions:**

Patients and their accompanying adults must be provided with written postoperative instructions on:

- **How to obtain emergency help?** So, communication between the patient and the day-case center is very important for help and follow up e.g. a phone contact.
 - How to perform **routine follow up care?**
 - **Abstaining** from drinking alcohol and taking any **depressant drugs** for 24 hours.
 - Patients should **not drive a car or operate machinery** for 24 hours because these street-fitness activities require complete psychomotor recovery which is often not achieved until 24-72 hours postoperatively.
- An outpatient must be discharged home **in the company of a responsible adult** who will stay with him or her over night.

B) Postoperative Complications:

They may cause unanticipated hospital admission which represent 1% of day-case anesthesia due to problems during PACU.

A. Anesthetic Complications:

1) Postoperative Nausea and Vomiting (PONV):

- They are the **most common** causes of unexpected hospital admission.
- Risk factors increasing postoperative nausea and vomiting:

Patient Factors:

- 1- **Young age** and children (equal in males and females until puberty).
- 2- **Female gender** especially if **menstruating** on the day of surgery.
Or if **in the 1st trimester** of the pregnancy (high estrogen).
- 3- **History** of prior postoperative vomiting or history of motion sickness.
- 4- **Early ambulation** and **sudden movement** of the patient.
- 5- **Delayed gastric emptying** e.g. obesity, excessive anxiety.....

Anesthetic Technique:

- 1- **Opioids** especially large doses.
- 2- **Prolonged GA time.**
- 3- **Assisted mask ventilation.**
- 4- **Anesthetic drugs** (neostigmine, ketamine, N₂O, and volatile agents).
- 5- **Postoperative pain.**
- 6- **Hypotension.**

Certain Surgical Procedures:

- | | |
|------------------------|----------------------------|
| 1- Strabismus surgery. | 2- Varicose vein stripping |
| 3- Laparoscopy. | 4- D and C. |

5- Orchiectomy.

7- Tonsillectomy and Ear surgery.

6- Ovum retrieval.

8- Breast Augmentation.

Prophylactic Treatment: especially in high risk patients.

1- Antiemetics e.g. droperidol, metoclopramide 10 mg i.v, ondanesetron 4 – 8 mg i.v, dolasetron 50 mg i.v, dexamethazone 150 µg/kg up to 8 mg, trans-dermal hyoscine patch 2 hours before surgery (but may cause anticholinergic side effects), or a combination of them which is more beneficial.

2- Order **no oral intake including fluids until the patient feels hungry**. If the patient feels thirst (without hunger), the patient can be relieved by gargling water, but swallowing should be avoided.

Treatment of PONV:

1- Antiemetics as above (in prophylaxis).

2- Adjuvants to antiemetics:

- **Stimulation of the Nei-Guan P6 acupoint** by acupuncture, electro-acupuncture, transcutaneous acupoint electrical stimulation (TAES), and acupressure.
- Use of **supplemental O₂** (i.e. FiO₂ = 0.8, balance nitrogen) as 80% O₂ intraoperatively decreases PONV over the 1st 24 hours by half (44% vs. 22%) compared to 30% O₂.
- **Aggressive i.v. rehydration** as patients receiving 20 mL/Kg of i.v. fluids had a decreased incidence of thirst, drowsiness, and dizziness compared to patients receiving 2 mL/Kg.

2) Postoperative Pain:

- Treatment should start **intraoperatively** inside the OR (not post-recovery) by:

1- **Opioids.**

2- **Ketorolac** 0.5-1 mg/kg iv/im. It is given before the end of surgery. It does not cause nausea or vomiting or respiratory depression.

3- **Local anesthetics** e.g. caudal block or penile block especially in pediatrics.

4- **Acetaminophen** 25-40 mg/kg rectally or orally (after return of oral intake in the recovery).

5- **New CoX-2 specific inhibitors** e.g. parecoxib 20-50-100 mg i.v/i.m without GIT side effects of other NSAIDs.

3) Other Minor Anesthetic Complications:

• **Prolonged somnolence (delayed awakening):** Especially after long acting anesthetic drugs.

• **Headache:** Especially after subarachnoid block.

• **Urinary retention:** Especially after subarachnoid or epidural block.

• **Sore throat and hoarseness:** Especially after intubation.

• **Post-anesthetic croup:** Especially in pediatrics.

• **Muscle pain (myalgia):** Especially after suxamethonium.

• **I.v. site problems** and skin injuries.

B. Medical Complications:

• **CVS:** Hypertension, hypotension, arrhythmias, CHF, myocardial ischemia.....etc.

• **Pulmonary:** Atelectasis, bronchospasm, aspiration.....etc.

C. Surgical Complications:

• **Bleeding.**

• **Unsuccessful procedures**

CHAPTER 32

EMERGENCY ANESTHESIA

ANESTHESIA FOR MAJOR TRAUMA

PATIENT

- Trauma is the leading cause of death in Americans 1-35 years of age.
- Deaths from trauma occur either:

- **Early:** 80% of deaths • 50% immediately.
- 30% within the first few hours of injury.

The causes of death in the early group are **preventable** so, named 'golden hour' i.e. the time elapsing between an injury and definitive surgical care.

- **Late:** 20% of deaths.

- Role of anesthesiologists in trauma patients is to;

- 1) Provide the initial resuscitation.
- 2) Provide anesthesia for surgical treatment.

N.B.; Permissive Hypotension:

Definition: It is the hypothesis that **fluid resuscitation should be delayed until surgical control of hemorrhage** has taken place. This concept is applied in the treatment of hypotensive trauma patients.

Value: The administration of large volumes of intravenous fluids (aggressive fluid treatment) prior to surgical control of bleeding is felt by some to be potentially deleterious because;

- It **increases ABP** (even up to normotensive pressure) and **vessel diameter**.
- It **decreases blood viscosity**.
- It **dilutes platelets and clotting factors**.

- These actually will promote further **blood loss** increasing the mortality in severe uncontrolled hemorrhage e.g. ruptured abdominal aortic aneurysm or penetrating truncal injury.

- Therefore, it is accepted now to obtain lower than normal mean ABP until surgical control of hemorrhage is achieved within 1 hour. During permissive hypotension, the usual resuscitation is employed e.g. vascular access.....etc. After effective surgical hemorrhage control, rapid warmed fluid loading is established to restore organ perfusion.

Contraindications: Permissive hypotension is **not allowed** in shocked multiple trauma patients **with head injuries** because the preservation of cerebral perfusion pressure to prevent secondary brain injury by ischemia is the vital goal. Therefore, early operative intervention to stop hemorrhage and simultaneous volume replacement to achieve normovolemia and normotension are required.

Anesthetic Management:

Preoperative Management:

A) Initial (Primary) Assessment:

By A, B, C sequence of cardiopulmonary resuscitation.

It is Airway, Breathing and Circulation. It is not Accuse, Blame or Criticize.

1) Airway: By:

- Removal and **suction** of blood, secretions or teeth.

- Securing airway by: - **Jaw thrust** maneuver.
 - Oropharyngeal or nasopharyngeal **airway**.
 - **Intubation** especially of unconscious patients who are at risk of aspiration.
 - **Tracheostomy** with local anesthesia.
 - **Emergency cricothyrotomy** for acute obstruction of upper airway.

With care in trauma patients for;

- **Cervical spine fracture** (even if there is no known injury).
 - Detected by history (as in alert patient, it often produces neck pain or tenderness), neck x-ray or CT scan.
 - Avoid neck hyperextension and intubation should be with **in-line immobilization**. Apply neck stabilization by sandbags, forehead tape or Philadelphia collar.
- **Other vertebral fractures** so; care should be taken during patient transportation. The patient should be transported in one line (figure 32-1).

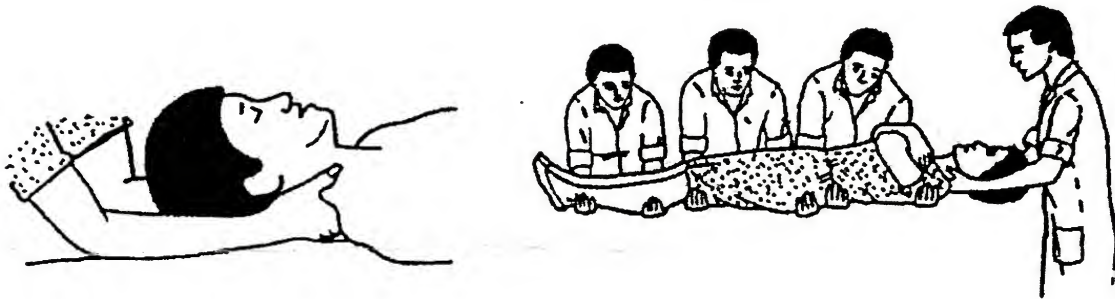


Figure 32-1; Patient transportation

- **Mid-face or basilar skull fractures:** avoid nasal intubation or nasopharyngeal airways.

2) Breathing:

- Most critically ill trauma patients require assisted ventilation by bag-valve devices e.g. a **self inflating bag** with a non-rebreathing valve connected to face masks or E.T.T.
- **100% O₂** is given till arterial oxygenation is assessed by AB gases.
- Patients with suspected head trauma need hyperventilation to decrease ICP.

3) Circulation:

- **Assess the volemic status:**see management of hypovolemic shock.
- Multiple large bore i.v. cannulas (14 – 16 gauge) either peripheral (easier) or central.

B) Later Assessment:

1) Assessment of the Injury and Other Associated Injuries:

- This is usually done by a specialist by history, examination and investigations.
- E.g. - General surgery for abdominal injury.
 - Neurosurgery for head injury.
 - Cardio-thoracic for chest injury.
 - Orthopedic surgery for bone fractures.

They determine the surgical diagnosis and the type of the surgery needed.

- They are essential to be determined as they dictate the extent of preoperative preparations and methods of anesthesia.

2) Assessment of the Past Medical Condition: (history, examination, and investigation).

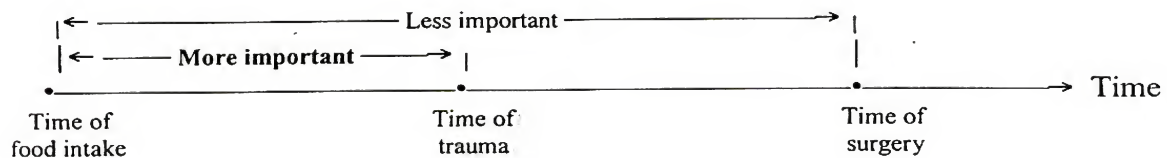
- It is usually taken from the relatives (if the patient is a child or is comatosed).

3) Airway Assessment for Difficult Intubation:

- Especially in cases of head and face trauma (airway trauma).

EMERGENCY ANESTHESIA**4) Assessment of Aspiration:**

- **Precautions against aspiration** should be taken.....
 - **All trauma patients** must be considered as having a **full stomach** as gastric emptying stops at the time of significant trauma due to fear, pain, shock, opioids...etc.
- Therefore, in all trauma patients, the time interval between ingestion of food and the accident is a more reliable index of the degree of gastric emptying than the period of fasting.

**5) Premedications:**

- 1- Sedatives are better avoided.
- 2- Prophylaxis against aspiration.
- 3- O₂ by a face mask.

Intraoperative Management:

Try to postpone surgery as much as possible to allow proper preoperative resuscitation before the induction.

Monitoring:

They should be inserted **before induction of anesthesia**. It includes the standard +

- **UOP** by Foley's catheter and urinometer.
- **Temperature** (core and skin).
- **CVP, PCWP, and invasive ABP** according to the patient's condition and the type of surgery.
- **AB gases.**
- Blood sample is sent to the laboratory to monitor **PCV and coagulation**.

Choice of Anesthesia:**A) Regional Anesthesia:**

- It is usually **impractical in hemodynamically unstable patients** e.g. brachial plexus block, i.v. regional anesthesia, subarachnoid or spinal block.

B) General Anesthesia:**Induction:**

- If the patient is unconscious; intubation should be done by a paralyzing dose of suxamethonium only.
- If the patient is conscious;

1- Rapid Sequence Induction:

- Careful **assessment for difficult tracheal intubation** should be done. If it is suspected, shift to either **regional anesthesia, inhalational or awake intubation**.
- Patient position:
 - It should be on a **tipping trolley or table with an adjustable head piece** to alter the degree of neck extension/flexion quickly.
 - Ideally, the patient is put in **the sniffing position** with the neck flexed on the shoulders and the head extended on the neck.
 - The optimum position is that in which the anesthetist has gained the greatest experience in performing intubation.

Some prefer the **reverse trendelenburg (head-up) position to prevent regurgitation.**

And others prefer the **trendelenburg (head-down) position to prevent aspiration.**

- **A skilled assistant** should be present to perform cricoid pressure, assist in turning of the patient and supply stillettes and tubes.
- **A good suction** apparatus must be within reach of the anesthetist's hand.
- **Check the anesthetic machine** and adjust ventilator setting before induction.
- **Preoxygenation** with 100% O₂ for 3-5 minutes.
- Pre-induction measurement of HR, ABP, and inspection of ECG.
- **Cricoid pressure (sellick's maneuver):**

It should be done by a skilled assistant by applying firm pressure by the **thumb and fore-finger** of the right hand over the cricoid cartilage in a posterior direction. This **compresses the esophagus** between the cricoid cartilage and the vertebral column because the cricoid cartilage forms a **complete ring**. The tracheal lumen is not distorted. It is applied just before the i.v. agent or as soon as consciousness is lost and maintained until the cuff of the E.T.T is inflated and its correct placement in the trachea is confirmed by auscultation (figure 32-2).

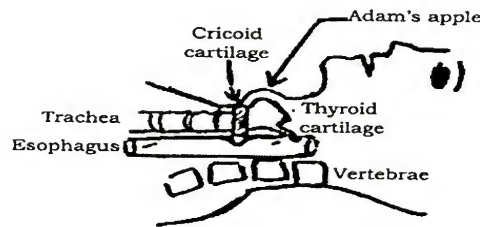


Figure 32-2; Cricoid pressure

- Thiopentone, etomidate or ketamine (not in head injury) is followed immediately by suxamethonium. Intubation is done without waiting.

2- Inhalational Induction:

- It is used if there is doubt about controlling the airway e.g. maxillofacial trauma.
- Guard against aspiration by putting the patient in the lateral or supine position with cricoid pressure.

3- Awake Intubation (Fiberoptic Intubation):

- It is of choice in patients who are likely to develop un-relievable airway obstruction when loss of consciousness occurs e.g. trismus from dental abscess and angio-neurotic edema.

Maintenance:

Apply a balanced technique of anesthesia by;

• Anesthesia (loss of consciousness)

By N₂O: O₂ + low MAC volatile agent (halothane 0.5, isoflurane 0.5%-1% or enflurane 0.5%-1%).

N.B.; Drugs as **ketamine** and **N₂O** indirectly stimulate cardiac function in normal patients. They can display **cardio-depressant effects in shocked patients** who already have maximal sympathetic stimulation. N₂O is avoided by some anesthesiologists for this cause and also to increase FiO₂ and the possibility of pneumothorax in trauma patients.

- **Analgesia:** by small i.v. doses of opioids e.g. fentanyl or morphine.
- **Muscle relaxants:** by non-depolarizing muscle relaxant, its choice depends on the patient's condition e.g. pancuronium increases the HR (so; it is the best in hypovolemic patients, but not in ischemic patients).

Controlled ventilation: - Minute ventilation → 100 mL/Kg/min.
 - Tidal volume → 8-12 mL/Kg.
 - Peak airway pressure → minimal.

- Fluid management.

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- Temperature management.

Recovery:

- Discontinue the volatile agent 5-10 min before the end of surgery.
- With the last skin suture, direct laryngoscopy is done to remove secretions and debris from the pharynx.
- Aspirate nasogastric tube if present.
- Reverse muscle relaxant.
- Awake extubation in the lateral position.

Postoperative Management:

- 1- Postoperative **pain relief**.
- 2- Postoperative **complications** e.g. hypothermia, DIC, or ARDS.
- 3- Postoperative prophylactic (elective) ventilation in;
 - Prolonged shock (hypoperfusion) state of any cause.
 - Massive sepsis e.g. focal peritonitis, cholangitis, or septicemia....
 - Severe ischemic heart disease.
 - Extreme obesity.
 - Overt gastric acid aspiration.
 - Previously severe pulmonary disease.

Special Management in Severely Traumatized Patient:

1. **Hypovolemic shock:** one of the major causes of death in trauma.....See C.V.S Anesthesia.
- 2- **Head trauma:** one of the major causes of death in trauma.....See CNS Anesthesia.
- 3- **Spinal cord trauma:**See CNS Anesthesia.
- 4- **Chest trauma:**See anesthesia with respiratory diseases
 - ARDS.
 - Pneumothorax and tension pneumothorax.
 - Lung contusion, and hemothorax.
 - Cardiac tamponade.See Anesthesia for CVS diseases.
 - Myocardial contusion (**Blunt Cardiac Trauma or Injury**).
 - Traumatic aortic rupture.
 - Valvular disruption, or septal rupture.
 - Traumatic diaphragmatic hernia.
 - Esophageal rupture.
- 5- **Abdominal Trauma:**
 - Wound of penetrating injury (usually).
 - Peritoneal irritation causing muscle guarding, and percussion tenderness.
 - Splenic rupture, liver or kidney injury causing severe hemorrhage.
 - X-ray abdomen shows free air.
 - Peritoneal lavage (**Paracentesis**).
- 6- **Extremity traumas:**
 - **Vascular injury** causing massive hemorrhage e.g. femoral fractures may be associated with 1500 mL of occult blood loss.
 - **Dislocations** so, care is taken during positioning.
 - **Neurovascular bundle injury** so, care is taken during positioning.
 - **Long bone and pelvis fractures** causing fat embolism leading to respiratory insufficiency.
 - **Microvascular reimplantation** surgeries may be needed.
- 7- **Airway trauma.**
- 8- **Burn.**

CHAPTER 33

FLUID AND ELECTROLYTE

DISTURBANCES

Basic Definitions:

Atom: Atomic number Atom^{Atomic weight} e.g. ${}^8\text{O}^{16}$

Atomic weight; it is the weight of the atom in relation to oxygen atom (which is 16) or hydrogen atom (which is one)

Atomic number; it is the number of electrons or protons of the atom.

Molecular Weight (MW): It is the weight of one molecule in Dalton i.e. the summation of the weights of atoms e.g. $\text{H}_2\text{O} = 2 \text{ H atom} \times 1 + \text{one O} \times 16 = 18 \text{ Dalton}$

Gram-Molecular Weight: It is the molecular weight in grams. It represents one mole e.g. for $\text{NaCl} = 23 + 35.5 = 58.5 \text{ grams}$.

Mole: One mole of substance represents 6.02×10^{23} molecules (Avogadro's number).

Molarity: It is the system international (SI) unit of concentration that expresses the number of moles of solute per liter of solution.

Equivalency:

- It is used for substances that ionize.

- The number of equivalents of an ion in solution is the number of moles multiplied by its charge (valence) i.e. **Equivalents = n^o of moles x valence**.

For monovalent ions e.g. Na^+ or Cl^- : $\text{Eq/L} = \text{mol/L}$ or $\text{mEq/L} = \text{mmol/L}$.

For bivalent ions e.g. Ca^{++} or Mg^{++} : $\text{mEq/L} = \text{mmol/L} \times \text{valence}$

e.g. Ca^{++} in $\text{mEq/L} = 2 \text{ Ca}^{++} \text{ mmol/L} \times 2 = 4 \text{ mEq/L}$

i.e. $2 \text{ mmol Ca}^{++} = 4 \text{ mEq Ca}^{++}$.

- A one molar solution of $\text{MgCl}_2 = 2$ equivalents of magnesium (2 valence x 1 mole) /liter + 2 equivalents of chloride (1 valence x 2 mole)/liter.

Osmosis:

It is the net movement of solvent (water) across a semi-permeable membrane due to a difference in non-diffusible solute concentrations between the two sides.

Osmotic Pressure:

It is the pressure that must be applied to the side with more solute to prevent a net movement of water down the concentration gradient. It is generally dependent on the number (rather than type) of non-diffusible solute particles.

E.g. Ionizing substances exert a greater osmotic pressure than non-ionizing substances as 1 mmol of NaCl exerts an osmotic pressure of 2 mosmol while protein exerts less osmotic pressure.

Osmole:

It is the unit which represents the amount of osmotically active particles present in solution. E.g.:

a. For non-ionized substance:

180 gm glucose i.e. molecular weight in gram (one mole) in 1 liter of water represents a solution with a molar concentration of 1 mol/liter and an osmolality of 1 osmole/liter i.e. for glucose, one mol/L = one osmol/L.

b. For ionized substance:

NaCl ionizes in solution and each ion represents an osmotically active particle.

Actually, ionic interaction between the cation and anion reduces the effective activity of each so that NaCl behaves as if it is only 75% ionized.

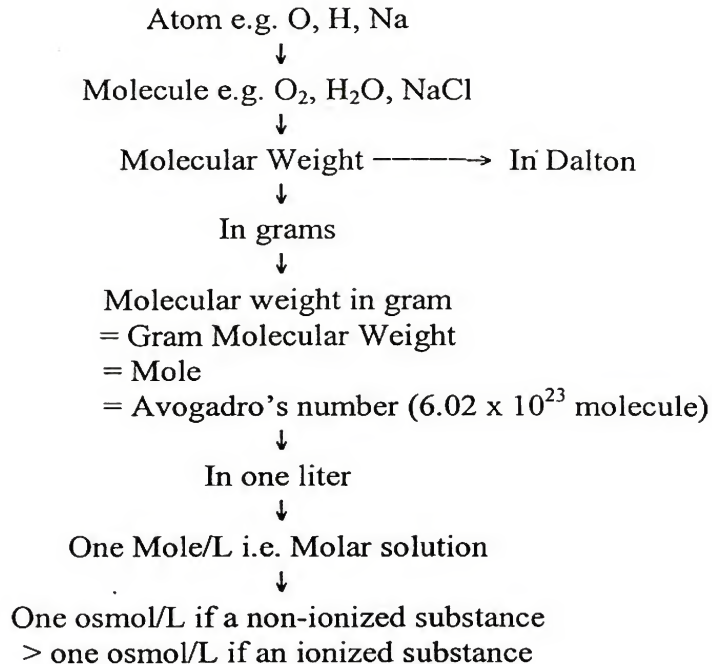
• Assuming complete dissociation of NaCl into Na^+ and Cl^- , 58.5 gram of NaCl (molecular weight in gram) dissolved in 1 liter of water has a molar concentration of 1 mol/liter and an osmolality of 2 osmol/liter.

• In body fluids, solute concentrations are much lower (mmol/liter) and dissociation is incomplete. So, a solution of NaCl containing 1 mmol/liter contributes slightly less than 2 mosmol/liter

FLUID AND ELECTROLYTE DISTURBANCES

I.e. For NaCl, one mol/L = $n \times \text{osmol/L}$.
 = $2 \times \text{osmol/L} = 2 \text{ osmol/L}$.
 = Less than 2 osmol/L in the body fluids.

I.e. one osmol/L is produced by one mol/L for the non-ionized substances.
 More than one osmol/L is produced by one mol/L for the ionized substances.

**Osmolarity:**

It is the number of osmoles per **liter** of solution (i.e. the volume of solvent)
 i.e. osmol/liter (or osm/L).

Osmolality:

It is the number of osmoles per **kilogram** of solution (i.e. the weight of solvent)
 i.e. osmol/Kg.

In body fluids, both are nearly equal.

E.g. plasma osmolarity (mosmol/liter) = plasma osmolality (mosmol/Kg) = 280-310.

Because - **The solvent** in the body fluid is the **water** which has a density of one
 i.e. osmol/liter = osmol/kg.

- **The solutes' volume** contained in biological fluids is **negligible**.

Tonicity:

- It is the **effect** a solution has on **cell volume**.

- It describes the effective osmotic pressure of a solution relative to that of plasma.

o An **isotonic** solution has the same osmolality of plasma and has no effect on cell volume.

o A **hypotonic** solution has less osmolality than plasma and increases cell volume.

o A **hypertonic** solution has more osmolality than plasma and decreases cell volume.

- The critical difference between osmolality (a chemical term) and tonicity (a physiologic term) is that all solutes contribute to osmolality, but only solutes that do not cross the cell membrane contribute to tonicity. Thus **tonicity expresses the osmolar activity of solutes restricted to the EC compartment i.e. those which exert an osmotic force affecting the distribution of water between ICF and ECF.**

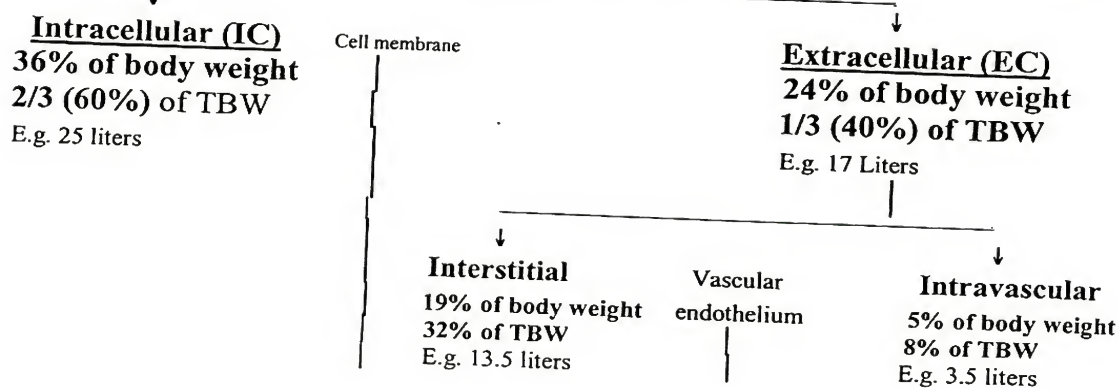
- Mannitol and sorbitol do **not** diffuse across cell membrane, so they are only present in ECF so, they contribute **to both osmolality and tonicity**.
- Plasma osmolality = $2 [Na^+] + [glucose] + [urea]$

Plasma tonicity = 290 mosmol/Kg.
 = 2 [Na⁺] mmol/L + blood glucose mmol/L
 = 285 mosmol/Kg.

Total Body Water (TBW)

Total Body Water (TBW)
60% of the body weight in an adult male e.g. 70 Kg man = 42 liters.
50% of the body weight in an adult female e.g. 60 Kg woman = 30 liters.

50-55% of the body weight in an adult **female** (due to more fat content which contain less water)



Composition of Fluid Compartments:

	Gram MW	Intracellular	Interstitial	Intravascular
Sodium (mEq/L)	23.0	10	142	142
Potassium (mEq/L)	39.1	150	5	5
Chloride (mEq/L)	35.5	4	110	105
Bicarbonate (mEq/L)	61.0	10	28	24
Calcium (mEq/L)	40.1	< 1	3	3
Magnesium (mEq/L)	24.3	50	2	2
Phosphorus (mEq/L)	31.0	75	2	2
Protein (gm/dL)	-	25	0	60-80
Osmolality (mosmol/L)	-	285	285	285

N.B.; Changing from mg/dL (mg %) to mmol/L:

$$\text{mmol/L} = \frac{\text{mg\%} \times 10}{\text{MW}} = \frac{\text{mg/L}}{\text{MW}}$$

1) Blood glucose 90 mg/dL:
 i.e. $90 \text{ mg}/100 \text{ mL} = 900 \text{ mg/L}$
 MW of glucose = $180 \text{ gm} = 1 \text{ mole}$.

So; 1 mmol/L \rightarrow 180 mg
X \rightarrow 900 mg/L
So; 900 mg/L (90 mg/dL) = $900/180 = 5$ mmol/L

2) NaCl 0.9%: i.e. 0.9 gm / 100 mL

I.e. $900 \text{ mg}/100 \text{ mL} = 9000 \text{ mg/L}$

MW of NaCl = 58.5 gm

So; 1 mmol/L \rightarrow 58.5 mg/L

X → 9000 mg/L

So; $0.9 \text{ gm \%} = 1 \times 9000 / 58.5 = 150 \text{ mmol/L}$

FLUID AND ELECTROLYTE DISTURBANCES**Water Balance (Homeostasis)**

- Normal day-to-day fluctuations in the total body water are small ($< 0.2\%$) due to a fine balance between input controlled by the thirst mechanism.

and output controlled by the renal-ADH system.

- The adult daily water intake (sources)	= 2500 mL.
* Ingested fluid	1300 mL.
* Water in solid food	800 mL.
* Water produced as an end product of metabolism	400 mL.
+ I.v. fluids are another common source in hospital patients.	
- The adult daily water losses (output)	= 2500 mL.
* Insensible - Skin evaporation	400 mL.
- Skin sweat	100 mL.
- Lung evaporation	400 mL.
* Sensible - Urine	1500 mL.
- Feces	100 mL.

N.B.: Types of Gaps: 1- Osmolar gap in plasma. See later

2- Osmolar gap in stools. See later

3- Anion gap. See later

4- Auscultatory gap. See before.

5- Window gap in hepatitis, in which there is a decrease in Ig M while Ig G is not yet increased. So; the patient is infectious, but this does not appear in serology.

Exchange between fluid compartments

Capillary fluid exchange (Starling's forces). It is 1st described in 1896 (figure 33-1).

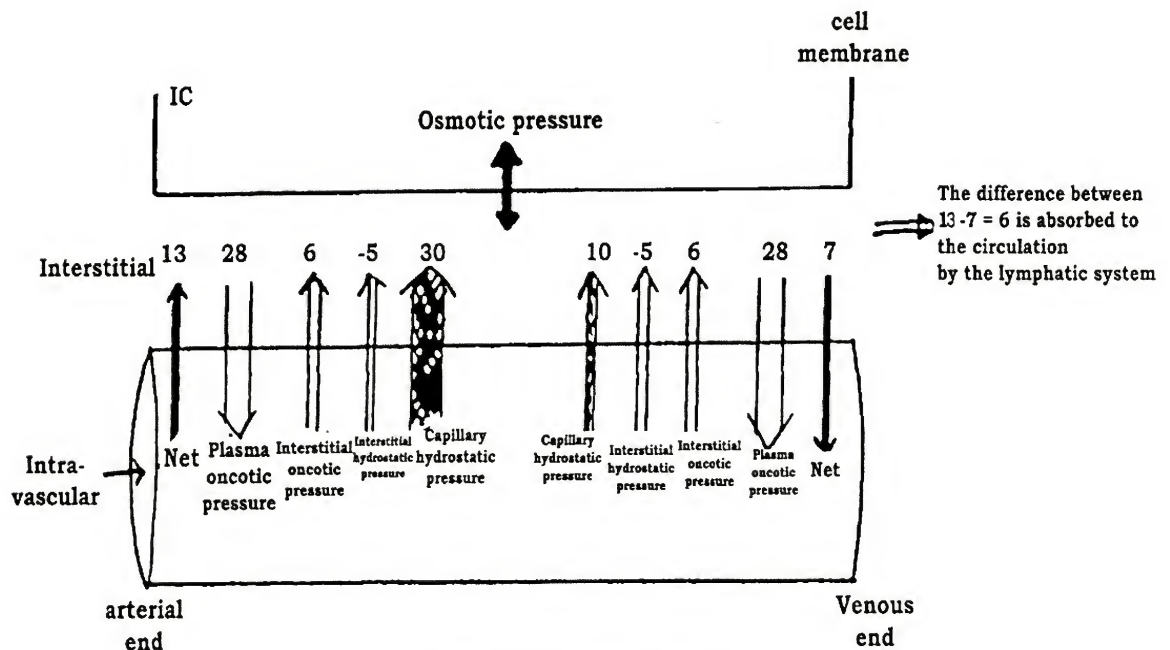


Figure 33-1; Starling's forces

Plasma Osmolality

Plasma osmolality

$$= 2 \times [\text{Na}^+] \text{ mmol/L} + \text{blood glucose mmol/L} + \text{blood urea (BUN) mmol/L}$$

$$= 2 \times [\text{Na}^+] \text{ mmol/L} + \frac{\text{blood glucose mg/dL}}{18} + \frac{\text{blood urea mg/dL}}{2.8}$$

$$= 280\text{-}290 \text{ mosmol/L or mosmol/Kg.}$$

Control of Plasma Osmolality:

It is done by osmoreceptors in the hypothalamus which control both;

- Urine excretion by antidiuretic hormone (ADH).
- Water intake by thirst mechanism.

a. Urine Excretion (Anti-Diuretic Hormone, ADH):

- Specialized neurons in the **supraoptic and paraventricular nuclei of the hypothalamus** are very sensitive to changes in the EC osmolality. They synthesize ADH where it is transferred to posterior pituitary to be stored.

- When ECF **osmolality increases**, these cells shrink. So, **ADH (arginine vasopressin 'AVP')** is released from the posterior pituitary. This increases **water reabsorption** markedly in renal collecting tubules which decreases **plasma osmolality** to the normal levels again. The reverse occurs with decreased ECF osmolality.

B. Water Intake (Thirst):

Osmoreceptors in the lateral pre-optic area of the hypothalamus are also very sensitive to changes in EC osmolality.

So, increased ECF osmolality stimulates these cells, leading to thirst and the individual drinks water and vice versa.

The effect of different fluids on plasma osmolarity and volume:

2 Rules are present:

Rule I:

All infused Na^+ remains in the ECF, Na^+ can not gain access to the ICF due to the Na^+ pump. So, if saline 0.9% is infused, all Na^+ remains in the ECF. As this is an isotonic solution, there will be no change in ECF osmolality and therefore no water exchange occurs across the cell membrane. So, saline 0.9% expands the ECF volume.

If saline 0.45% is given, ECF osmolality decreases which leads to shift of the water from the ECF to the ICF.

If saline 1.8% is given, ECF osmolality increases which leads to shift of the water from the ICF to the ECF.

Rule II:

Water infusion (without Na^+) expands the total body water. After infusion of a solution of glucose 5%, glucose enters the cells and is metabolized. **The infused water enters both the ICF and the ECF in proportion to their initial volumes.**

- From the above principles, the effects of different fluids on compartmental water and plasma osmolality can be calculated.

1000 mL i.v. fluid	ECF	ICF	Remarks
• Saline 0.9%	+1000	0	<ul style="list-style-type: none"> • Na^+ remains in the ECF due to the Na^+ pump, so it can not enter the ICF. • As it is isotonic, water remains in the ECF.
• Saline 0.45%	+666	+333	<ul style="list-style-type: none"> • Na^+ remains in the ECF. • As it is hypotonic, water shifts from the ECF to the ICF. • 33% of total body water is ECF.
• Glucose 5%	+333	+666	<ul style="list-style-type: none"> • Water is distributed according to the ICF & the ECF volume ratio. • 66% of total body water is ICF.

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• Saline 1.8%	+1000 + More from ICF	-ve	• Na ⁺ remains in the ECF. • As it is hypertonic, water shifts from the ICF to the ECF
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Q: Discuss Plasma Osmolarity?

A: Definition and equations.

Control of plasma osmolarity.

Effect of fluids on plasma osmolarity.

Hyper- and hypo-osmolarity.

Sodium Balance

Normal s. Na⁺ = 135-150 mEq/L.

Regulation of Na⁺ Balance: (and ECF volume)

The ECF volume is directly proportionate to the total body Na⁺ content. So; the control of one is intimately tied to the other.

Several mechanisms regulate intravascular volume as increased intravascular volume increases urinary Na⁺ excretion and the reverse.

1. Renin-Angiotensin-Aldosterone System: (baroreceptors in the juxta-medullary apparatus)

Changes in ABP at the afferent renal arterioles affect the baroreceptors in the juxta-medullary apparatus. Increased intravascular volume (preload) increases CO which increases ABP. **Increased ABP stimulates the baroreceptors which inhibits juxta-medullary apparatus.** Therefore, juxta-medullary apparatus **decreases aldosterone effect so, Na⁺ reabsorption is decreased** in the proximal and distal tubules (mainly) which **increases Na⁺ excretion.**

2. Pressure Natriuresis: (Carotid Sinus Baroreceptors)

Changes in ABP and so; changes in intravascular volume will affect the CO and so; affect the ABP.

- Increased ABP stimulates baroreceptors at the carotid sinus which leads to;
 - Decreased sympathetic stimulation which in turn decreases Na⁺ reabsorption in proximal renal tubules increasing Na⁺ excretion.
 - Decreased non-osmotic secretion of ADH decreases EC volume in case of a moderate to severe increase in the intravascular volume (and the reverse).
- Increased ABP (even a small increase) without any known humoral or neural mediated mechanisms, produces a large increase in the urinary Na⁺ excretion.

3. Sympathetic Activity: (Carotid Sinus Baroreceptors)

- Sympathetic stimulation causes;
 - An increase in Na⁺ reabsorption in the proximal renal tubules decreasing Na⁺ excretion.
 - Renal VC decreases renal blood flow which in turn decreases the GFR.
 - The cardio-renal reflex (the reverse occurs)
- Stimulation of left atrial stretch receptors (by the increased volume) decreases the renal sympathetic tone which increases the renal blood flow and GFR.

4. Atrial Natriuretic Peptide (ANP): (Atrial Stretch Receptors)

- **Stretch receptors in both atria detect atrial distension**

So; increased intravascular volume causes atrial distension which leads to the release of ANP which;

- Increases urinary Na⁺ and H₂O excretion in renal collecting tubules (mainly).
- Produces afferent arteriolar VD which increases the GFR.
- Produces efferent arteriolar VC which increases the GFR.
- causes both renin and aldosterone secretion.
- Antagonizes ADH.

5. Antidiuretic Hormone: (Atrial Stretch Receptors)

- **Stretch receptors in both atria detect atrial distension**

So, increased intravascular volume increases atrial distension which decreases ADH release.

- Non-osmotic secretion of ADH. See before.....

6. Tubulo-Glomerular Balance:

- Decreased GFR decreases the filtration fraction which decreases peri-tubular capillary oncotic pressure which in turn decreases Na^+ reabsorption. See renal physiology (renal blood flow).

EC Volume Regulation Versus Osmoregulation:

Osmoregulation protects the normal ratio of solutes to water, whereas EC volume regulation preserves absolute solute and water content.

Differences between the 2 mechanisms:

	Volume Regulation	Osmoregulation
Purpose	Control of EC volume i.e. preserve absolute solute and water content.	Control of EC osmolality i.e. preserve the normal ratio of solute to water.
Mechanisms	By altering the renal Na^+ excretion.	By altering the water intake (thirst) and renal water excretion.
Sensors	<ul style="list-style-type: none"> • Afferent renal arterioles (juxta-medullary) • Carotid baroreceptors. • Atrial stretch receptors. 	<ul style="list-style-type: none"> • Hypothalamic osmoreceptors.
Effectors	<ul style="list-style-type: none"> • Renin-angiotensin-aldosterone. • Renal pressure natriuresis. • Sympathetic nervous system. • Atrial natriuretic peptide. • Anti-diuretic hormone. • Tubulo-glomerular balance. 	<ul style="list-style-type: none"> • Thirst. • Anti diuretic hormone.

Generally, volume regulation takes precedence over osmoregulation.

Hyper-osmolality & Hypernatremia	Hypo-osmolality & Hyponatremia
<p>S. Na^+: > 150 mmol/L</p> <p>Hyperosmolality is not always associated with hypernatremia. Other causes of hyperosmolality:</p> <ol style="list-style-type: none"> 1- Marked hyperglycemia. 2- Those receiving large amount of glycine (as during TURP). 3- Marked hyperlipidemia or hyperproteinemia 4- Chronic renal failure (i.e. retention of small solutes). 5- Ketoacidosis (i.e. high concentration of ketone bodies). <p>N.B: Causes form (2) to (5) produces discrepancy between the measured and calculated osmolality i.e. significant osmolar gap.</p> <p>Causes of Hypernatremia: (assess ECV)</p> <p>a. Low total body Na^+ content: Loss of water > loss of Na^+ → ↓EC volume</p> <ol style="list-style-type: none"> 1. Renal: <ul style="list-style-type: none"> • Osmotic diuresis as hyperglycemia, and mannitol. 2. Extra-renal: <ul style="list-style-type: none"> • Osmotic diarrhea. • Vomiting. • Sweat. <p>b. Normal total body Na^+ content: Loss of water only so; ECF at 1st becomes normal then decreases</p> <ol style="list-style-type: none"> 1. Renal: <ul style="list-style-type: none"> • Diabetes insipidus • Chronic renal failure. 2. Extra-renal: <ul style="list-style-type: none"> • Burns. • Thyrotoxicosis. • Fever. 	<p>S. Na^+: < 135 mmol/L</p> <p>Hypo-osmolality is nearly always associated with hyponatremia Causes of pseudo-hyponatremia: I.e. hyponatremia without hypo-osmolality.</p> <ol style="list-style-type: none"> 1- Hyperglycemia. 2- Large amount of glycine. 3- Hyperlipidemia or hyperproteinemia. 4- Mannitol administration. <p>Causes of Hyponatremia: (assess ECV)</p> <p>a. Low total body Na^+ content: (depletional) Loss of Na^+ > loss of water → ↓EC volume</p> <ol style="list-style-type: none"> 1. Renal: <ul style="list-style-type: none"> • Osmotic diuresis as hyperglycemia, mannitol. • Diuretics especially thiazides. 2. Extra-renal: - Urine Na^+ < 15 mosm/L <ul style="list-style-type: none"> • Diarrhea. • Vomiting <p>b. Normal total body Na^+ content: Modest excess of Water → EC volume is normal.</p> <ol style="list-style-type: none"> 1. Syndrome of inappropriate ADH: e.g. <ul style="list-style-type: none"> - Some malignant tumors produce ADH like substances as lung, prostate and pancreas. 2. Syndrome of inappropriate i.v. therapy due to administration of i.v. fluids with low Na^+ content to patients with isotonic losses e.g. D_5W. 3. Glucocorticoid deficiency & Addison's disease. 4. Hypothyroidism.

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<p>c. High total body Na^+ content: $\uparrow \text{Na}^+$ intake > water $\rightarrow \uparrow$ EC volume.</p> <ul style="list-style-type: none"> • Hypertonic saline (3%) or isotonic saline in patient with only insensible loss as renal failure. • NaHCO_3 therapy. • 1ry hyperaldosteronism. • Cushing's syndrome. 	<p>5. Renal failure. 6. Drug induced (they decrease UOP)</p> <ul style="list-style-type: none"> • \uparrow ADH secretion <ul style="list-style-type: none"> - Barbiturates. - Opioids. - Hypoglycemic as chlorpropamide and tolbutamide. • Potentiate ADH at distal tubules. <ul style="list-style-type: none"> - Paracetamol. - Indomethacin. - Chlorpropamide <p>c. High total body Na^+ content: \uparrow Water intake > Na^+ $\rightarrow \uparrow$ EC volume (edema)</p> <ol style="list-style-type: none"> 1. Congestive heart failure 2. Cirrhosis 3. Nephrotic syndrome 4. Renal failure (it makes the urine Na^+ to be > 20 mmol/L). <p>2ry hyperaldosteronism</p>
<p>C/P:</p> <ul style="list-style-type: none"> - Severity depends on the rapidity with which EC Hyperosmolality develops i.e. the rate of movement of water out of the brain cells than with the absolute Na^+ levels. - Mainly CNS due to cellular dehydration. • $[\text{Na}^+] 150\text{-}158 \text{ mmol/L} \rightarrow$ CNS (+) <ul style="list-style-type: none"> • Lethargy, restlessness and hyperreflexia. • Pyrexia (impaired thermoregulation). • Nausea and vomiting (impaired chemoreceptor trigger zone) • $[\text{Na}^+] > 158 \text{ mmol/L} \rightarrow$ CNS (++) <ul style="list-style-type: none"> • Seizures, coma and finally death (with prolonged hypernatremia over 48 hours). • Rapid decrease in brain volume causes rupture of cerebral veins leading to focal intracranial or subarachnoid hemorrhage. - Decreased EC volume (with decreased total Na^+) lead to signs of hypovolemia. - Normal or decreased EC volume (with normal total Na^+) leads to signs of water loss without overt hypovolemia unless the water loss is massive i.e. 10-15% of TBW 	<p>C/P:</p> <ul style="list-style-type: none"> - Severity depends on the rapidity with which EC Hypo-osmolality develops i.e. the rate of movement of water inside the brain cells than with the absolute Na^+ levels. - Mainly CNS due to cellular overhydration (water intoxication). • $[\text{Na}^+] 125\text{-}135 \text{ mmol/L} \rightarrow$ Asymptomatic. • $[\text{Na}^+] 120\text{-}125 \text{ mmol/L} \rightarrow$ Nonspecific as anorexia, nausea and weakness. • $[\text{Na}^+] < 120\text{-}115 \text{ mmol/L} \rightarrow$ Cerebral edema, lethargy, confusion, seizures, coma and finally death. - Decreased EC volume causes signs of hypovolemia. - Increased EC volume causes signs of hypervolemia and edema.
<p>Treatment:</p> <p>It is a medical emergency.</p> <p>1- Treatment of the cause:</p> <p>E.g. • Central diabetes insipidus: Desmopressin, synthetic analogue of vasopressin (ADH) as intranasal preparations.</p> <ul style="list-style-type: none"> • Adrenal or thyroid hyperfunction: Surgical treatment <p>2- Treatment of hypernatremia:</p> <ol style="list-style-type: none"> a- With low total body Na^+ content (with \downarrow ECV) <ul style="list-style-type: none"> • 1st replace isotonic fluid deficit by isotonic fluid. • Then replace water deficit (see below). b- With normal total body Na^+ content (normal ECV) <ul style="list-style-type: none"> • Replace water deficit c- With high total body Na^+ content (high ECV) <ul style="list-style-type: none"> • 1st give loop diuretics (to increase Na^+ excretion). • Then replace any water deficit. <p>Water deficit:</p> <ul style="list-style-type: none"> - It is replaced by D_5W. - The amount required (water deficit) is calculated as; Normal TBW x Normal s. $[\text{Na}^+] =$ Measured TBW x Measured s. $[\text{Na}^+]$ So; Measured TBW = $\frac{\text{Normal TBW} \times \text{Normal s. } [\text{Na}^+]}{\text{Measured s. } [\text{Na}^+]}$ <p>Normal TBW = Body weight x 60/100 (60% of body weight is water).</p> <p>But, Water deficit = Normal TBW - Measured TBW</p>	<p>Treatment:</p> <p>It is a medical emergency.</p> <p>1- Treatment of the cause:</p> <p>E.g. • Inappropriate ADH syndrome: Democlocycline (ADH antagonist) or lithium.</p> <ul style="list-style-type: none"> • Adrenal or thyroid hypofunction: Replacement hormones. <p>2- Treatment of hyponatremia:</p> <ol style="list-style-type: none"> a- With low total body Na^+ content (with \downarrow ECV) <ul style="list-style-type: none"> • 1st replace isotonic fluid deficit by isotonic fluid. • Then replace Na^+ deficit (see below). b- With normal total body Na^+ content (normal ECV) <ul style="list-style-type: none"> • Restrict water intake. c- With high total body Na^+ content (high ECV) <ul style="list-style-type: none"> - Congestive heart failure, cirrhosis or nephrotic syndrome cause; • 1st give loop diuretics or spironolactone (to increase Na^+ excretion). • Then restrict water intake. - Renal failure: Restrict water intake. <p>Na^+ deficit:</p> <ul style="list-style-type: none"> - It is replaced by normal saline. - Na^+ deficit (required) $= \text{TBW} \times (\text{Desired } [\text{Na}^+] - \text{measured } [\text{Na}^+])$ E.g. : 80 Kg woman with s. $[\text{Na}^+] 118 \text{ mmol/L}$ Na^+ deficit = $\text{TBW} \times (\text{Desired } [\text{Na}^+] - \text{measured } [\text{Na}^+])$ $= (80 \times 0.5) \times (130 - 118) = 480 \text{ mmol}$

<p>E.g. : 70 Kg man with s. $[Na^+]$ 160 mmol/L Normal TBW x Normal s. $[Na^+] =$ Measured TBW x Measured s. $[Na^+]$ $(70 \times 0.6) \times 140 =$ Measured TBW x 160</p> <p>Measured TBW = $\frac{70 \times 0.6 \times 140}{160} = 36.7$ L</p> <p>Water deficit = Normal TBW - Measured TBW = $(70 \times 0.6) - 36.7 = 5.3$ L</p> <p>To replace this deficit over 48 hour by D₅W i.v. i.e. 5300 mL over 48 hour i.e. = 110 mL/hour.</p> <p>N.B.; Avoid rapid correction of hypernatremia as it causes brain edema, seizures and permanent neurologic damage up to death. So; serial serum osmolality should be obtained during treatment. In general s. $[Na^+]$ should not be decreased faster than 0.5 mmol/L/hour.</p>	<p>Normal isotonic saline contain 154 mmol/L so; the patient should receive $480 \div 154$ mmol/L or 3.12 liter of normal saline in rate of 0.5 mmol/L/hour. So; it needs 24 hours i.e. 130 ml/ hour.</p> <p>N.B.; Avoid rapid correction of hyponatremia as it causes demyelinating lesions in the pons (central pontine myelinolysis, osmotic demyelinating syndrome). It causes serious permanent neurologic sequelae as paralysis, coma and even death. So; the following rates are recommended:</p> <ul style="list-style-type: none"> • For mild symptoms → 0.5 mmol/L/hr or less. • For moderate symptoms → 1.0 mmol/L/hr or less. • For severe symptoms → 1.5 mmol/L/hr or less. <p>Rapid correction is achieved by:</p> <ul style="list-style-type: none"> • Loop diuretics: to induce water diuresis while replacing urinary Na^+ losses with isotonic saline. • I.V hypertonic saline (3%): for more rapid correction, over 12 hours, but it is given cautiously as it may precipitate pulmonary edema especially in patients with high total body Na^+ content. So; only correct s. $[Na^+]$ up to 125 mmol/L. <p>Hypertonic saline 3% contains 514 mmol/L of Na^+.</p>
<p>Anesthetic Considerations:</p> <ul style="list-style-type: none"> - Elective surgeries should be postponed in patients with hypernatremia > 150 mmol/L till it is corrected. - The associated hypovolemia: • It accentuates VD or cardiac depression from anesthetic agents and predisposes to hypotension and hypoperfusion of tissues. • There is decreased volume of distribution for drugs. So; decrease the doses of most i.v agents. A decreased CO enhances the uptake of inhalational agents. 	<p>Anesthetic Considerations:</p> <ul style="list-style-type: none"> - Elective surgeries should be postponed in patients with hyponatremia < 130 mmol/L till it is corrected. - The associated cerebral edema: • It decreases the MAC intraoperatively. • It produces agitation, confusion or somnolence postoperatively.

Potassium Balance

Normal s. $K^+ = 3.5-5.5$ mEq/L.

Regulation of K^+ Balance: (Inter-compartmental shift)

1. Exercise: (↑)

- It increases the plasma $[K^+]$ about 0.3-2 mmol/L due to the release of K^+ by muscle cells depending on the intensity and duration of muscle activity.

2. Changes in EC $[H^+]$ Ions (i.e. pH):

- Because ICF may buffer up to 60% of an acid load.

a- During acidosis: EC H^+ ions enter the cells displacing IC K^+ ions and causing movement of the K^+ ions out of the cells to maintain the electric balance. This increases plasma $[K^+]$.

b- During alkalosis: EC H^+ ions leave the cells moving EC K^+ ions into the cells to maintain the electrical balance. This decreases plasma $[K^+]$.

- Plasma $[K^+]$ changes approximately 0.2-1.2 (average 0.6) mmol/L per 0.1 unit change in arterial pH.

3. Changes in Circulating Insulin Level: (↓)

- Insulin enhances the activity of membrane-bound Na^+-K^+ ATPase which increases cellular uptake of K^+ in the liver and skeletal muscle. This decreases plasma $[K^+]$.

4. Sympathetic Activity:

- Sympathetic β_2 receptor stimulation enhances the activity of membrane-bound Na^+-K^+ ATPase which increases cellular uptake of K^+ in the liver and skeletal muscle. This decreases plasma $[K^+]$ while β_2 antagonists increases plasma $[K^+]$.

FLUID AND ELECTROLYTE DISTURBANCES**5. Plasma Osmolality:**

- An acute increase in plasma osmolality (hypernatremia, hyperglycemia or mannitol administration) causes movement of the water out of cells (down its osmotic gradient) leading to cellular dehydration which increases IC K^+ . This causes movement of K^+ out of cells which increases plasma $[K^+]$ (about 0.6 mmol/L per 10 mosm/L).

6. Hypothermia:

- It causes cellular uptake of K^+ decreasing plasma $[K^+]$.
 - Rewarming reverses this shift leading to a transient increase in plasma $[K^+]$ resulting in hyperkalemia, if K^+ was given during the hypothermia.

Hyperkalemia	Hypokalemia
- S. K^+ : > 5.5 mmol/L	- S. K^+ : < 3.5 mmol/L
Causes: (a) Inter-compartmental K^+ Shift: <ol style="list-style-type: none"> 1. Severe exercise. 2. Hyperkalemic periodic paralysis. 3. Tissue breakdown e.g. after chemotherapy, burns, trauma, and massive i.v. hemolysis. 4. Suxamethonium (It increases s. K^+ about 0.5 mmol/L) which is exaggerated with large burn, severe muscle trauma, and spinal cord injury. 5. Acidosis. 6. β_2 antagonist. 7. Digitalis toxicity. (b) Decreased Renal K^+ Loss: <ol style="list-style-type: none"> 1. Renal failure. 2. Isolated decreased K^+ secretion in distal nephrons as noncompetitive K^+ sparing diuretics (amiloride, triamtrine), sickle cell disease, renal allograft, SLE and urinary obstruction. 3. Decreased mineralo-corticoid activity as: <ul style="list-style-type: none"> - 1ry adrenal insufficiency (Addison's disease). - Competitive K^+ sparing diuretics (spironolactone). - Heparin, NSAIDs, cyclosporine. - Acquired immuno-deficiency syndrome (AIDS). (c) Increased K^+ Intake: <ul style="list-style-type: none"> * Transfusion of old whole blood (s. K^+ can be increased up to 30 mEq/L in 1 unit of transfused blood after 21 days of storage). * K^+ intake especially - If it is given i.v. rapidly. <ul style="list-style-type: none"> - In patients on β_2 antagonists. - With renal impairment. - With insulin deficiency. (d) Pseudo-Hyperkalemia (Factitious): <ul style="list-style-type: none"> * In vitro, RBCs hemolysis commonly due to prolonged use of tourniquet while obtaining a venous sample. * Marked leukocytosis > 70000 /μL leads to in vitro release of K^+ from WBCs in blood sample. * Marked thrombocytosis > 1000 000 /μL leads to in vitro release of K^+ from WBCs in blood sample. All cause false laboratory results.	Causes: (a) Inter-compartmental K^+ Shift: <ol style="list-style-type: none"> 1. Hypokalemic periodic paralysis. 2. Alkalosis. 3. Insulin administration. 4. β_2 agonist. 5. Hypothermia. (b) Increased K^+ Losses. <ul style="list-style-type: none"> • Renal: (urinary K^+ > 20 mmol/L) <ol style="list-style-type: none"> 1. Diuretics. 2. Ketoacidosis. 3. Renal tubular acidosis. 4. Renal artery stenosis (high renin). 5. Hypomagnesemia. 6. Renal failure (diuretic phase). 7. Increased mineralo-corticoid activity as: <ul style="list-style-type: none"> - 1ry hyperaldosteronism. - 2ry hyperaldosteronism (edematous disorders, reno-vascular hypertension, renin secreting tumor). - Mineralocorticoid tumors, glucocorticoid excess. • Extra-renal: (Urinary K^+ < 20 mmol/L) <ol style="list-style-type: none"> 1. Diarrhea, laxative abuse. 2. Vomiting, nasogastric suctioning. 3. Fistula, urinary diversion with uetero-sigmoid-ostomy. 4. Villous adenoma. 5. Pancreatic tumors secreting vasoactive intestinal peptide. 6. Sweat. 7. Dialysis with low K^+ containing dialysate solution. (c) Decreased K^+ Intake: Only contributory.
C/P: (1) Asymptomatic (2) C.V.S: <ol style="list-style-type: none"> 1. Contractility is well preserved. 2. Cardiac effects of hyperkalemia are enhanced by hyponatremia, hypocalcemia and acidosis. 3. ECG changes (in this order) Due to delayed ventricular depolarization. * At $K^+ \geq 7$ mmol/L - Symmetrical tall peaked T wave.	C/P: (1) Asymptomatic: with s. K^+ > 3 mmol/L. (2) C.V.S: <ol style="list-style-type: none"> 1. Contractility is depressed. 2. Orthostatic hypotension. 3. Arrhythmia. 4. Myocardial fibrosis (with chronic hypokalemia). 5. ECG changes: Due to delayed ventricular repolarization. - T wave flattening or inversion.

<ul style="list-style-type: none"> - Shortened QT interval. * At K^+ 8-10 mmol/L - Widening of QRS complex. - Prolonged PR interval. - Loss of P wave. - Loss of R wave. - ST segment depression or elevation. - Sine wave pattern: wide QRS complex merges into T wave. * At $K^+ > 10$ mmol/L - Ventricular fibrillation and asystole. <p>(3) Skeletal Muscle:</p> <ul style="list-style-type: none"> - Weakness progressing to flaccid paralysis. 	<ul style="list-style-type: none"> - Apparent U wave. - ST segment depression. - Increased P wave amplitude. - Prolonged PR interval. <p>(3) Skeletal Muscle:</p> <ul style="list-style-type: none"> - Weakness (especially quadriceps) and cramping. - Tetany. - Ileus. - Rhabdomyolysis. <p>(4) Renal:</p> <ul style="list-style-type: none"> - Nephrogenic DI (i.e. resistance to ADH) causing polyuria. - Increased HCO_3^- reabsorption leading to metabolic alkalosis. - Increased Na^+ retention.
<p>Treatment:</p> <p>(1) Treatment of the cause.</p> <p>(2) Treatment of hyperkalemia. (when s. K^+ is $> 6 - 7$ mmol/L)</p> <p>1- Ca^{++} i.v.: over 5 min.</p> <ul style="list-style-type: none"> - Ca gluconate 10%: 0.5 mL/Kg, max. 20 mL. Or - Ca chloride 10%: 3-5 mL. <p>* Ca^{++} will antagonize the cardiac effects of hyperkalemia without affecting s. $[K^+]$.</p> <p>2- In Case of Metabolic Acidosis: $NaHCO_3$ i.v. 1.5-2.0 mmol/kg over 5-10 min promotes cellular uptake of K^+ which decrease s. $[K^+]$ within 15 min.</p> <p>3- β_2 Adrenergic Agonist:</p> <ul style="list-style-type: none"> - E.g. Epinephrine low dose (0.5-2 μg/min). - It promotes cellular uptake of K^+ and inotropic support. - It is used in acute hyperkalemia associated with massive transfusions. <p>4- I.v. infusion (glucose + insulin): 50 gm glucose per 20 Units of insulin or 0.5-1.0 gm/kg glucose + 0.3 unit/kg insulin.</p> <ul style="list-style-type: none"> - It is given as a bolus then i.v. infusion according to blood glucose. - They are more effective than $NaHCO_3$, but takes up to 1 hour for peak effect. <p>5- Furosemide:</p> <ul style="list-style-type: none"> - If there is some degree of renal failure. <p>6- Non-absorbable cation exchange resins: As</p> <ul style="list-style-type: none"> * Ca^{++} resonium. <p>7- Dialysis (in severe refractory cases).</p> <ul style="list-style-type: none"> - Hemodialysis (maximal K^+ removal is 50 mmol/h) is more efficient and faster than peritoneal dialysis (maximal K^+ removal is 10-15 mmol/hr). 	<p>Treatment:</p> <p>(1) Treatment of the cause.</p> <p>(2) Treatment of hypokalemia by K^+ administration.</p> <p>Route:</p> <p>a. Oral KCl solution: 60-80 mmol/day (the safest over several days).</p> <p>b. I.v.: in patients with serious heart and muscle affection.</p> <ul style="list-style-type: none"> - Via peripheral i.v. vein: the rate should not exceed 8 mmol/hr as it is irritant to peripheral veins. - Via central i.v. vein: the rate can be 10-20 mmol/hr. <p>Precautions:</p> <ul style="list-style-type: none"> * Continuous ECG monitoring especially in i.v. route. * Never exceed - Rate 0.5 mmol./Kg/hr. - Dose 240 mmol/day. <p>(to allow equilibrium with ICF)</p> <ul style="list-style-type: none"> * Avoid dextrose-containing solution as the resulting hyperglycemia and 2ry insulin secretion decreases s. $[K^+]$ further. <p>Types:</p> <ul style="list-style-type: none"> * KCl is of choice with metabolic alkalosis as it corrects chloride shifts. * K^+ bicarbonate, K^+ acetate or K^+ citrate is of choice with metabolic acidosis. * K^+ phosphate is of choice with coexisting hypophosphatemia (e.g. diabetic Ketoacidosis).
<p>Anesthetic Considerations:</p> <ul style="list-style-type: none"> - Elective surgery should be postponed until treatment of hyperkalemia. - ECG monitoring is essential. - Avoid: * Suxamethonium. - * K^+ containing solutions as lactated ringer's. - * Acidosis (metabolic or respiratory) to prevent further hyperkalemia. - Hyperkalemia accentuates muscle relaxant effects so; a nerve stimulator is essential. 	<p>Anesthetic Considerations:</p> <ul style="list-style-type: none"> - Elective surgery should be postponed until treatment of hypokalemia. (N.B., Chronic mild hypokalemia (3-3.5 mmol/L) without ECG changes has no anesthetic risk). - ECG monitoring is essential. - Avoid: * Glucose containing solutions. - * Alkalosis (as hyperventilation) as it further decreases $[K^+]$. - * Hypokalemia in patients on digitalis as it causes digitalis toxicity so; keep s. $K. \geq 4$ mmol/L. - Hypokalemia increases the sensitivity to muscle relaxants so; a nerve stimulator is essential.

Hypercalcemia	Hypocalcemia
<p>S. Ca^{++}: > 10.5 mg/dL</p> <p><u>Causes:</u></p> <ol style="list-style-type: none"> 1. Hyperparathyroidism and hyperthyroidism. 2. Malignancy. 3. Excessive Vitamin D or A intake. 4. Paget's disease of the bone. 5. Granulomatosis as sarcoidosis or TB. 6. Chronic inflammation. 7. Adrenal insufficiency. 8. Drug induced as thiazide and lithium. 9. Milk alkali syndrome. 	<p>S. Ca^{++}: < 8.5 mg/dL</p> <p><u>Causes:</u></p> <ol style="list-style-type: none"> 1. Hypoparathyroidism e.g. surgical, burns, idiopathic. 2. Pseudo-hypoparathyroidism. 3. Vitamin D deficiency e.g. nutritional, gastrectomy. 4. Hyperphosphatemia. 5. Precipitation of Ca^{++} e.g. pancreatitis, fat embolism, rhabdomyolysis. 6. Chelation of Ca^{++} e.g. Multiple transfusion, liver disease, renal disease, hypothermia, rapid infusion of large amounts of albumin.
<p><u>C/P:</u></p> <ul style="list-style-type: none"> • CNS: Ataxia, irritability, lethargy, confusion up to coma. • CVS: ECG changes - Short ST segment. - Short QT interval. • Muscle: Weakness. • GIT: Anorexia, nausea and vomiting, pancreatitis and peptic ulcer. • Renal failure: Polyuria. 	<p><u>C/P:</u></p> <ul style="list-style-type: none"> • CNS: Parasthesia, confusion, or seizures. • CVS: Arrhythmia and heart failure. ECG changes - Prolonged QT interval. • Muscle: Spasm - Laryngeal spasm (stridor). - Carpopedal spasm (Trousseau's sign) - Masseter spasm (Chvostek's sign). - Bronchospasm. - Biliary spasm (biliary colic).
<p><u>Treatment:</u></p> <p>It is a medical emergency.</p> <ol style="list-style-type: none"> 1. Treatment of the cause. 2. Saline infusion + loop diuretics. 3. Dialysis; if there is renal or heart failure. 	<p><u>Treatment:</u></p> <p>It is a medical emergency.</p> <ol style="list-style-type: none"> 1. Treatment of the cause. 2. Ca^{++} administration over 5 min either: <ul style="list-style-type: none"> * I.v. Ca^{++} gluconate 10% 0.5 mL/kg max. 20 mL. (10 mL of Ca^{++} gluconate 10% contains only 93 mg of Ca^{++}). * I.v. Ca^{++} chloride 10% 3-5 mL. (10 mL of Cacl 10% contains 272 mg of Ca^{++} because chloride molecule is about 1/3 of the weight of the gluconate molecule). - To avoid precipitation, i.v. Ca^{++} should not be given with HCO_3^- or phosphate containing solutions. - Serial Ca^{++} and Mg^{++} measurement is essential.

Anesthetic Considerations:

- Elective surgeries should be **postponed** until treatment of hypocalcemia as it is a medical emergency.
- **ECG monitoring** is essential.
- **Avoid alkalosis.**
- I.v. Ca^{++} is needed after rapid transfusion of citrated blood products or large volume of albumin solutions.
- With muscle relaxants, variable effects may occur so; a **nerve stimulator** is essential.

Magnesium Balance

Mg⁺⁺ Function:

Hypermagnesemia

Hypomagnesemia

S. Mg^{++} : < 1.5 mEq/L

Causes:

1. Decreased Mg intake: as prolonged fasting or hyperalimentation.
2. Decreased GIT absorption: e.g. **Malabsorption, diarrhea**, fistula, or prolonged nasogastric suction.
3. Increased renal loss: e.g. **Diuresis** (diuretics or hyperglycemia), diabetic **ketoacidosis**, hypophosphatemia, and drugs as cisplatin, **aminoglycosides**, and amphotericin.
4. Others: **Chronic alcoholism, burns, pancreatitis, and hyperthyroidism.**

C/P: (+)

1. CNS: paresthesia, confusion, ataxia, and seizures.
2. Muscle: Weakness and fasciculation.
3. CVS: ECG - Prolonged PR interval.
- Prolonged QT interval.
4. Associated hypokalemia and hypocalcemia.

Treatment:

1. Mg oxide orally.
2. Mg sulfate i.v or i.m.

Anesthetic Consideration:

- Avoid coexisting hypokalemia and hypocalcemia.**

Fluid Management

Intravenous Fluids

Crystalloid Solutions

Definition:

They are aqueous solutions of low molecular weight ions (salts) (< 30 000 Dalton) with intravascular half-lives, 20-30 minutes.

Types:

1. Hypotonic Solutions (Maintenance-Type Solutions):

- Uses: * For replacement of pure water deficits (losses).
 - * As maintenance fluid for patients on Na^+ restriction.
- e.g.: Dextrose 5% in water (D_5W).

2. Isotonic Solutions (Replacement-Type Solutions):

- Uses: For replacement of losses that involve both water and electrolyte deficits as most of intraoperative losses.

- e.g.:

* **Normal Saline (NS):** When it is used in large amounts, it produces a **dilutional hyperchloremic acidosis** due to its high chloride content (154 mmol/L), plasma HCO_3^- concentration decreases as chloride concentration increases. So; NS is the preferred solution for hypochloremic metabolic acidosis and for diluting packed RBCs prior to transfusion.

* **Lactated ringer's solution:** (the most commonly used): It is the **most physiologic solutions**. Its lactate content is converted by the liver into **bicarbonate**.

* **Ringer acetate solution:** It is recently introduced. It is better than ringer lactate because;

- It improves acid-base parameters in hypovolemic shock.
- It improves CO in burned patients.
- It does not decrease ketone bodies uptake with the liver insufficiency.
- It is recommended in lactic acidosis.
- It is metabolized in muscles unlike lactate which is mainly in the liver.

3. Hypertonic Solution:

- It should be given in central venous line slowly as they readily cause hemolysis.
- e.g.: * 3% saline: It is used in the treatment of severe symptomatic hyponatremia.
 - * 7.5% saline: It is used in resuscitation of patients in hypovolemic shock.
 - * 20% mannitol.

Composition of Crystalloid Fluids:

Solution	Osmolarity mosm/L	Na^+ mmol/L	Cl^- mmol/L	K^+ mmol/L	Glucose gm/L	pH	Others
• 5% dextrose in water (D_5W)	Slightly hypo 278				50 (278 mmol/L)	4.0	
• Normal saline 0.9% (NS)	Iso 308	154	154			5.0	
• D_5NS	Hyper 586	154	154		50		
• Ringer's injection	Iso 310	147.5	156	4			Ca^{++} 2.5 mmol/L
• Lactated ringer's injection (Compound Na lactate) (LR) (Hartmann's solution)	Slightly hypo 278	131	111	5		6.5	Ca^{++} 2.0 mmol/L Lactate 29 mmol/L which changed to HCO_3^-
• Ringer acetate injection	Slightly hypo 273.4	130	108.7	4			Ca^{++} 2.7 mmol/L Acetate 28 mmol/L
• NaHCO_3 8.4% (Molar solution)	Hyper 2000	1000				8.0	HCO_3^- 1000 mmol/L
• NaHCO_3 5%	Hyper 1190	595					595 HCO_3^-

N.B.; mEq = mmol for Na^+ , Cl^- , K^+ , HCO_3^- and Acetate.

mEq = mmol x 2 for Ca^{++} and Mg^{++}

Colloid Solutions (Plasma Volume Expanders)

Definition:

They are solutions containing high molecular weight substances (> 30 000 Dalton) with intravascular half lives of 4-6 hours (longer than crystalloids).

Uses:

1. Fluid resuscitation in patients with severe intravascular fluid deficits e.g. **Hemorrhagic shock:**

* **Before the arrival of blood** for transfusion.

Or * **Used with crystalloids** when the fluid replacement required exceeds 3-4 L before blood transfusion.

2. Fluid resuscitation in the presence of **severe hypo-albuminemia** or conditions associated with **large protein losses such as burns**.

Types:

a. Blood Derived Colloids:

1. Human Albumin (5%, 25%):

- Albumin 5% is iso-oncotic while albumin 25% is hyper-oncotic.
- Its MW is 69 000. Its half life is 18 - 20 days.
- It is prepared from human plasma.
- It carries a strong -ve charge at physiologic pH.
- It acts as a carrier protein for the transport and activation of drugs, hormones, enzymes, fatty acids, aminoacids, bilirubin, and other metabolites.
- It provides about 70% of the plasma colloid oncotic pressure in normal subjects.

2. Plasma Protein Fraction (PPF) (5%):

- Its albumin content is $\geq 83\% + \alpha$ and β globulins which may cause allergic reactions.
- It is prepared from pooled human blood, serum or plasma.

Both are heated to 60° C for at least 10 hours i.e. pasteurization to decrease the risk of transmitting hepatitis and other virally transmitted diseases.

b. Synthetic Colloids:

1) Dextrose Starches: (Maximal dose is 1.5 L)

Chemical Structure:

They are D-glucose polymers linked by α 1, 6 bonds into linear macromolecules, prepared from sucrose.

Types	Dextran 70 (Macrodex)	Dextran 40 (Rheomacrodex)
Half life	12 hours	12 hours
M. W.	70 000	40 000
Advantages	It is a better volume expander than dextran 40	It is better in improving the blood flow via micro-circulation by decreasing viscosity than dextran 70.

Disadvantages:

1. They have **anti-platelet effects** and they prolong the bleeding time (especially with dextran 40).
2. Infusions > 20 mL/Kg/day can **interfere with blood typing and compatibility tests** by the formation of rouleaux.
3. They are associated with **renal failure**.
4. They have an **antigenic effect** leading to anaphylactoid and anaphylactic reactions.

2) Gelatins: (Maximal dose is 1.5 L)

Types	Succinylated Gelatin (Gelifusine)	Polygeline (Haemaccel or Hemagel)
Half life	4 h	5 h
M. W.	30 000 - 35 000	30 000 - 35 000

FLUID AND ELECTROLYTE DISTURBANCESDisadvantages:

1. Histamine mediated **allergic** reactions due to the release of vasoactive substances leading to rash, hypotension and tachycardia.

- Advantages:

1. It does not interfere with blood grouping or compatibility tests.

2. It does not affect the renal functions.

3) Hydroxy-Ethyl Starch (-HES) (Etherified Starch) 6% (maximal dose is 1L)Chemical Structure:

- They are a group of polydisperse synthetic colloids that **resemble glycogen structurally**.

Examples:

- **Heta-starch:** (e.g. Hestrel) Its average MW is 450 000 (80% of particles with a MW ranging from 30 000 – 2500 000 Dalton). Its half life is 48 hours.
- **Penta-starch:** Its average MW is 200 000. Its half life is shorter (90% is eliminated within 24 hours).
- **Hextend:** Its MW is High. Its half life is longer.

Advantages:

1. They do not affect coagulation studies or bleeding times.
2. They are not antigenic, but only cause very rare anaphylactoid reactions.
3. They are very effective as plasma expanders.
4. They are less expensive than human albumin.

Clinically, several studies show:

1. **Crystalloids**, when they are given in sufficient amounts, they can be just as effective as **colloids** in restoring the intravascular volume. So, they are used for initial resuscitation.
2. **Replacing** an intravascular volume deficit with **crystalloids** generally requires ³⁻⁴ times the volume needed when using colloids.
3. Severe intravascular fluid deficits can be **more rapidly corrected** using **colloids** solutions.
4. The rapid administration of large amounts of **crystalloids** (> 4-5 L) is more frequently associated with decreased plasma oncotic pressure leading to **significant tissue edema**. So, continued fluid resuscitation should include colloids.

Marked tissue edema causes - Impairment of O₂ transport.

- Impairment of tissue healing.

- Impairment of return of bowel function after major surgery.

Peri-Operative Fluid Therapy

I. Normal Maintenance Requirements: (water losses are > solutes losses).

a. Normal Daily Requirement:

30-35 mL/Kg/day water for an adult (see pediatrics).

+ 1.0 mmol/Kg/day Na⁺.

+ 1.0 mmol/Kg/day K⁺.

+ 0.1 mmol/Kg/day Mg⁺⁺.

+ 10 mg/kg/day Ca⁺⁺ or P⁺⁺.

b. Normal Perioperative Requirement:

1st 10 Kg BW → 4 mL/Kg/hr.

+ 2nd 10 Kg BW → 2 mL/Kg/hr.

+ Each remaining Kg → 1 mL/Kg/hr.

E.g. In 70 Kg man, his maintenance requirement = 40 + 20 + 50 = 110 mL/hr.

Types:

- * D₅ ¼ NS or D₅ ½ NS as losses are normally hypotonic (water loss > Na⁺ loss).
- * Isotonic solution as LR can be used.

N.B.; D₅W is added to the 1st liter to prevent ketosis and hypoglycemia due to fasting.

II. Preexisting Deficits:

a. Fasting: It is calculated as the following; maintenance/hr x fasting hrs.

50% are given in the 1st hour, 25% in the 2nd hour and the last 25% in the 3rd hour.

b. Preoperative Deficits:

As vomiting, diarrhea, bleeding, ascitis.....

It should be replaced preoperatively.

III. Replacement Requirement: (surgical fluid losses)**a. Blood Loss:**

- Estimation of the volume lost: is done by;

* **Blood in the suction container** (care is taken to the use of irrigating solutions as this may lead to mis-estimation).

* **Visual estimation** of blood on surgical sponges and pads.

- Fully soaked sponge (4 x 4 cm) holds 10 mL of blood.

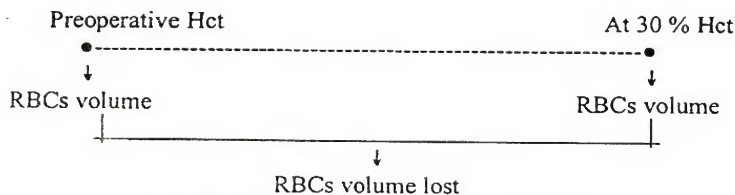
- Fully soaked pad (15 x 15 cm) holds 100-150 mL of blood.

Better assessment is done by **weighing** the sponges and pads before and after their use (especially in pediatrics).

* **Serial hematocrit or Hb** concentrations reflect the ratio of RBCs to plasma.

- Determination of the Transfusion Point:

The amount of blood loss necessary for the hematocrit to fall to 30% is calculated as follows:



So; allowable blood loss = RBCs volume lost x 3

1. Estimate the **blood volume**; see pediatric anesthesia (table).
 2. Estimate the RBC volume at preoperative hematocrit (RBCs V_{preop}).
 3. Estimate the RBC volume at hematocrit of 30% (RBCs $V_{30\%}$).
- Assuming that a normal blood volume is maintained.
4. Calculate the RBC volume lost when the hematocrit is 30%.

$$\text{RBCs } V_{\text{lost}} = \text{RBCs } V_{\text{preop}} - \text{RBCs } V_{30\%}$$

5. Allowable blood loss = RBCs $V_{\text{lost}} \times 3$

E.g. 85 kg female, her preoperative hematocrit = 35%.

- So; 1. Her blood volume = $65 \times 85 = 5525 \text{ mL}$
2. RBCs $V_{35\%} = 5525 \times 35\% = 1934 \text{ mL}$
3. RBCs $V_{30\%} = 5525 \times 30\% = 1657 \text{ mL}$
4. RBCs $V_{\text{lost at } 30\%} = 1934 - 1657 = 277 \text{ mL}$
5. Allowable blood loss = $277 \times 3 = 831 \text{ mL}$

So, transfusion should be considered when the patient's blood loss exceeds 800 mL.

N.B.; Other methods of calculation:

• Allowable blood loss = $(\text{Preoperative Hct} - \text{Hct}_{30\%}) / 100 \times \text{blood volume} \times 3$

• Allowable blood loss = $\frac{\text{Preoperative Hct} - \text{Hct}_{30\%}}{\text{Preoperative Hct}} \times \text{blood volume}$

FLUID AND ELECTROLYTE DISTURBANCES

- **Replacing Blood Loss:** is done by;

* **Before reaching the transfusion point:**

- Crystalloids (especially LR) 3-4 times the volume of blood lost are given.

Or - Colloids 1:1 times the volume of blood lost are given.

* **After reaching the transfusion point:**

- Whole blood or packed RBCs 1:1 times the volume of blood lost are given.

- Each one unit of RBCs increases the Hb 1 gm/dL and Hct 2-3% (in adults).

10 mL/Kg of RBCs transfusion increases Hb 3 gm/dL and Hct 10%.

b. Evaporative and 3rd Space Loss:

- **Evaporative Loss:**

It is directly proportionate to the exposed surface area of the wound and the duration of the surgical procedure.

- **3rd Space Loss:**

It is the fluid shifted from the i.v. compartment to the extra-vascular compartment (i.e. non-functioning) e.g. traumatized, inflamed, or infected tissues (as burns, extensive injuries, peritonitis), and surgical dissection.

They are replaced, according to the degree of tissue trauma, by lactated ringer solution.

* Minimal (e.g. herniorrhaphy) → 0-2 mL/Kg/hr.

* Moderate (e.g. cholecystectomy) → 2-4 mL/Kg/hr.

* Severe (e.g. bowel resection) → 4-8 mL/Kg/hr.

c. Abnormal Fluid Loss: - Due to;

- GIT: nasogastric suction, diarrhea, vomiting, or sequestered fluid in gut lumen e.g. intestinal obstruction.

- Urine.

- Insensible loss (from skin or lung): It increases during fever or hyperventilation.

BLOOD GROUPS

a. The ABO System:

- Almost all individuals not having A or B “naturally” produce antibodies (mainly Ig M which can not cross placenta) against these antigens **within the first year of life** (only after 3-6 months of age). This is not due to exposure to A or B antigens, but possibly due to exposure to other antigens (e.g. bacteria).

Type	RBCs antigen	Naturally occurring antibodies in serum (Ig M)	Incidence
A	A	Anti-B	42 %
B	B	Anti-A	8 %
AB	A and B	No antibodies	3 %
O	No antigen	Anti-A and anti-B	47 %
Type AB is a universal recipient.			
Type O is a universal donor.			
Rhesus D +ve 85 %.			
Rhesus D -ve 15 %.			

b. The Rh System: There are 50 Rhesus system antigens.

- About 80% - 85% of Caucasians have the D antigen and are called Rh +ve (D).

About 15% - 20% of Caucasians lacking the D antigen and are called Rh-ve (d).

The Rh-ve usually develop antibodies against the D antigen only after exposure to a previous Rh +ve transfusion or pregnancy (an Rh -ve mother delivering an Rh +ve baby). The probability of developing anti-D antibodies after a single exposure to Rh antigen is 50-70%. So; at least 2 pregnancies are required.

c. **Other Systems:** There are 200 non ABO/Rh antigens present.

- They include in order of frequency;

a- Common: Kell, Duffy, Kidd, Ss, and MNS.

b- Uncommon: Other rare types: Lutheran, Xg, Sid, Cart right, York, Chido, and Rodgers antigen.

- Fortunately, with a few exceptions, allo-antibodies against these systems rarely cause serious hemolytic reactions.

Emergency Transfusion

It is the need for transfusion before completion of cross-matching, screening or even blood typing.

a. **If the Patient's Blood Type is Known:**

- An **abbreviated cross match**, requiring < 5 minutes, will confirm ABO compatibility.

- Cross-matching assures optimal safety and detects the presence of less common antibodies which are not usually tested for in screen testing.

As the incidence of **serious hemolytic reactions** after the transfusion of an ABO and Rh compatible blood with a -ve screen test, but without cross matching is < 1%. So; cross-matching is performed only for elective surgical procedures where the probability of transfusion is high.

b. **If the Patient's Blood Type is not Known or not Available:**

- Type O Rh-ve (**universal donor**) blood may be used. In this instance, **packed RBCs** should be used instead of whole blood to minimize the transfer of anti-A and anti-B antibodies present in whole blood. These antibodies can react with the recipient's own RBCs (if A or B antigens are present) or with type-specific RBCs transfused subsequently. If > 2 units type O Rh -ve whole blood are used in an emergency, do not switch to the correct blood group (when blood bank determine and prepare it later), but continue giving type O Rh -ve whole blood. If the patient needs more blood units as this only causes minor hemolysis of recipient RBCs producing only hyper-bilirubinemia. The patient must not receive a blood unit of his correct blood type until the blood bank determines that the transfused anti-A and anti B have fallen to levels that permit safe transfusion of type-specific blood which usually takes a 2 week waiting period.

Preservation of Blood

A. Preservative-Anticoagulant Solution:

1. **ACD:** Shelf life 21 days.

A = Acid (citric acid).

C = Citrate (tri-sodium citrate)

D = Dextrose solution.

2. **CPD:** Shelf life 28 days.

C = Citrate which acts as anticoagulant by binding Ca^{++} .

P = Phosphate (Na dihydrogen phosphate) (NaH_2PO_4) which acts as a buffer, as it increases pH which increases RBCs survival in vivo.

D = Dextrose which acts as RBCs energy source.

3. **CPD-A:** Shelf life 35 days. (The most common used)

AS CPD

+ A = Adenine (precursor of ATP) which maintains ATP levels (as RBCs survival is related to cellular levels of ATP).

B. Appropriate Storage Temperature:

It is 2-6°C in a blood bank refrigerator.

Value:

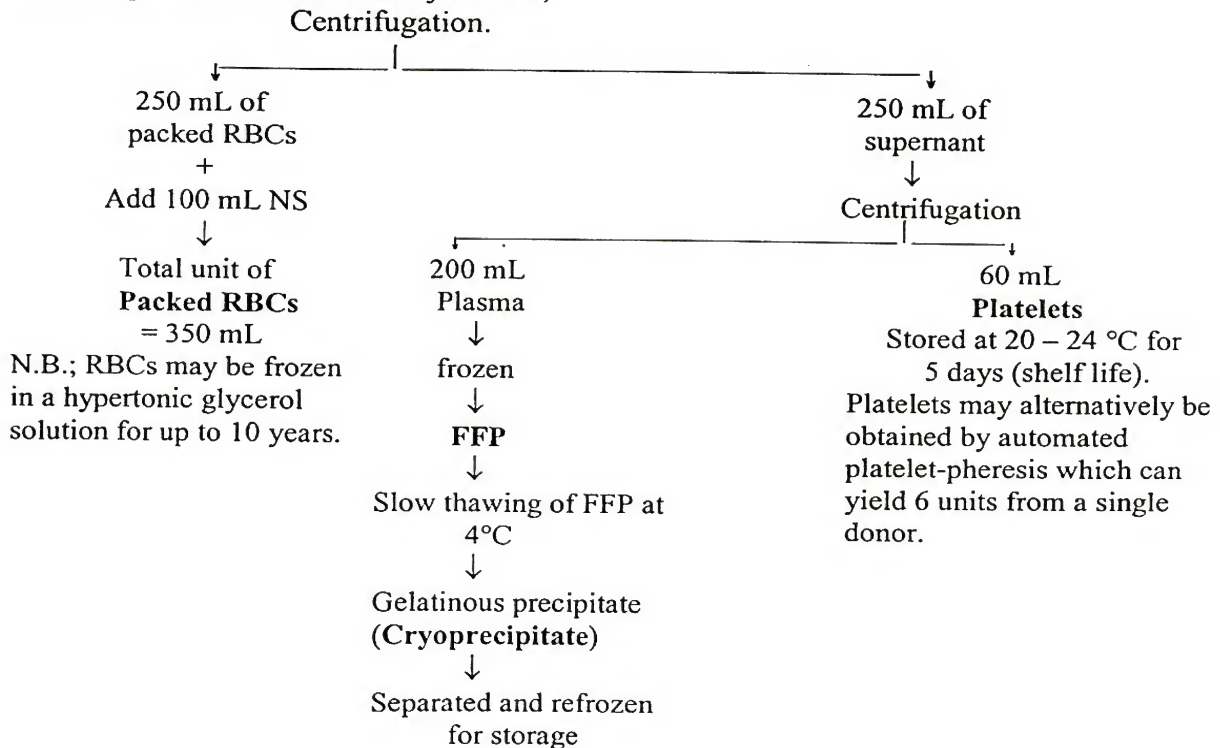
1. It inhibits bacterial replication in the blood.

FLUID AND ELECTROLYTE DISTURBANCES

2. It inhibits RBC glycolysis.
 3. It preserves some of 2, 3 Di-phospho-glycerate (2, 3 DPG) level (which is important in O₂ delivery to the tissues by RBCs)
(N.B.; Normal 2, 3 DPG level is 4.8 mmol/mL of erythrocytes).
- * With ACD, RBCs lose;
40% of 2, 3 DPG at 1 week which shifts O₂-Hb dissociation curve to the left and 90% of 2, 3 DPG at 2 weeks which shifts O₂-Hb dissociation curve to the left.
 - * With CPD, RBCs lose 20% of 2, 3 DPG at 2 weeks.
 - * With CPD-A, RBCs lose slightly < 20% of 2, 3 DPG at 2 week.
- Whatever the storage medium, the level of 2, 3 DPG return to normal with 6-24 hr after transfusion.

Preparation of Blood Components

450 mL of blood from a donor are added to 60 mL CPD-A so, a 510 mL unit of whole blood is produced which is subjected to;

**Blood Transfusion****Precautions:**

- Before transfusion, each unit should be **carefully checked** for;
- * The blood bank slip (**free from** hepatitis C and B, syphilis, HIV₁ and HIV₂, cytomegalovirus).
- * The blood bag **identification bracelet** for the patient's name and hospital number.
- * The **date of donation**.
- I.v. blood transfusion sets should contain **170 µm filters** to trap any clots or debris.
- All blood should be **warmed to 37°C** during infusion to avoid hypothermia which may cause tissue hypoxia.

Types of Blood Products:

(1) Whole Blood: (One unit = 450 – 510 mL)

- Stored and preserved as before.....

- Indications:

1. Acute blood loss in hypovolemic shock (slower rates of hemorrhages are managed with packed RBCs).
2. In surgical procedures with an expected blood loss of > 20% of blood volume in adults and 10% in children.
3. Hb < 8gm/dL (Hct < 26%).
4. Hb < 11gm/dL (Hct < 36%) and clinically symptomatic (C/P of anemia as tachycardia, angina, ECG changes or hemoglobinopathy) or high risk (e.g. CAD, COPD, CV stroke, congenital or acquired anemia).

(2) Packed RBCs: (Plasma-reduced cells or RBCs concentrates) (One unit = 250-310 mL)

- It should be the most commonly used blood transfusion because it allows optimal utilization of blood bank resources.

- Indications:

1. For patients requiring RBCs (but not volume replacement) e.g. An anemic patient in compensated congestive H.F.
2. When volume replacement is required (e.g. most surgical patients), **add normal saline** to the packed RBCs. **Avoid lactated ringer's injection** because its calcium content may reverse the anticoagulant effects of the citrate preservative and **avoid 5% glucose** because **it is distilled water** which may cause RBC hemolysis.

(3) Fresh Frozen Plasma (FFP): (One unit = 200 mL)

- It is stored frozen, once thawed; it must be transfused within 24 hours.
- It **contains all plasma proteins and lipids** including **all clotting factors**. Each unit of FFP generally increases the level of each clotting factor by 2-3 % in adults.
- **ABO compatible** units should generally be given, but **are not mandatory**.
- Some patients may become sensitized to plasma proteins. It can be as **infectious** as whole blood.

- Indications:

1. Treatment of;
 - * **Abnormal coagulation tests** as PT > 15 sec. or PTT > 45 Sec.
 - * **Isolated factor deficiency** either prophylactic before surgery or with bleeding.
2. The **reversal of warfarin** therapy.
3. The correction of coagulopathy associated with **liver diseases**.
4. In patients who have received **massive blood transfusions**.
5. In patients who **continue to bleed** after platelet transfusion.
6. **Anti-thrombin III deficiency** in patients who **must be anticoagulated with heparin**.
7. Thrombotic thrombocytopenic **purpura**.
8. Clinical evidence of **abnormal bleeding** from venipuncture and **generalized oozing**.
9. **Open heart surgery**, if transfusion is > 6 RBCs units/case.

- **Dose:** Initially **10-15 mL/Kg**.

(4) Platelets: (One unit = 50 – 70 mL)

- They are stored at **20 – 24 °C for 5 days** (shelf life). Platelet transfusion in particular may contain **proliferating bacteria** because they are stored at room temperature.
- **Each unit increases** the platelet count by **5000 – 10 000 / μ L** (a lesser increase is expected in patients with history of prior platelet transfusion due to rapid developing platelet antibodies in 70% of patients).
- **ABO-compatible** units are desirable (not cross matched), but **not mandatory**.
- Platelets may **cause Rh sensitization** due to the presence of a few RBCs in Rh +ve platelet units. So, administration of Rh immunoglobulins to Rh –ve patients can protect against Rh sensitization after Rh +ve platelet transfusion.

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- Transfused platelet survive for only 1-7 days after transfusion.

- Indications:

1. Thrombocytopenia (decreased platelet count):

* In presence of **bleeding** or **bleeding time > 10 min.**

* Prophylactic when **platelet count is < 20 000/ μ L** to avoid the risk of spontaneous hemorrhage.

* Prophylactic preoperative use when the platelet count is;

• <100 000/ μ L before major surgery.

• < 50 000/ μ L before minor surgery.

* In **open heart surgery**, if blood transfusion given is **> 6 RBCs units/case.**

* In **DIC.**

* In **massive blood transfusion** causing coagulopathy, if the platelet count is **< 40 000/ μ L .**

* In **autoimmune thrombocytopenia** (e.g. idiopathic thrombocytopenic purpura, ITP) with platelet count **< 10 000 / μ L).**

2. **Thromboasthenia** (platelet dysfunction), even if the platelet count is **> 100 000 / μ L, in;**

* Presence of bleeding.

* Preoperative prophylaxis especially for patients on NSAIDs, uremia, or after CP bypass.

- Dose:

* The standard dose is **4 units/square meter of body surface.**

Given as: - Twice on the day of surgery.

Then - 1/2 of the 1st dose at least 60 min preoperatively.

Then - Twice daily on the 1st and succeeding postoperative days according to the patient's progress.

* The usual therapeutic dose is **one unit platelet concentrate/10 Kg body weight within 24 hours period.**

(5) Granulocyte Transfusion:- Indications:

Neutropenic patients with bacterial infections not responding to antibiotics.

- Disadvantages: 1. Graft versus host reactions.

2. Pulmonary endothelial damage.

These disadvantages are decreased by irradiation of these units.

- Dose: Transfused granulocytes survive for a very short time, So, a **daily transfusion of 10-30 x 10⁹ granulocytes is required.**

(6) Cryoprecipitate:

- It contains high concentrations of factors I (fibrinogen), VIII (C and VW factor), IX and XIII.

- Indications:

1. Prophylaxis and treatment of **congenital fibrinogen deficiency.**

2. **Von Willebrand disease** and **hemophilia.**

3. **Massive blood transfusion.**

4. **Open heart surgery**, if transfusion is **> 6 RBCs units/case.**

5. **DIC.**

- Dose: One unit of cryoprecipitate/10 Kg body weight.

Complications of Blood Transfusion

A. Immune Complications:

1) Hemolytic Reactions: 1. Acute hemolytic reactions.

2. Delayed hemolytic reactions.

2) Non-hemolytic Reaction: 1. Febrile reaction.

2. Urticarial reactions.

3. Anaphylactic reactions.

4. Non-cardiogenic pulmonary edema.
5. Graft-versus-host disease.
6. Post-transfusion purpura.
7. Immune suppression.

B. Non-immune Complications:

- 1) **Complications of Massive Blood Transfusion:**
 1. Dilutional coagulopathy.
 2. DIC and fibrinolysis.
 3. Citrate toxicity.
 4. Hypothermia.
 5. S. K⁺ concentration.
 6. Acid-base balance.
 7. Impaired Hb function
- 2) **Complications of Old Stored Blood.**
- 3) **Infections.**

A. Immune Complications:

They are primarily due to sensitization of the recipient (antibodies in the patient's serum) to donor RBCs, WBCs, platelets or plasma proteins (rarely due to the transfused cells or serum against the recipient's cells).

1) Hemolytic Reactions:

Cause:

There is specific **destruction of transfused RBCs** by the recipients' antibodies (less commonly hemolysis of a recipient's RBCs due to the transfusion of RBCs antibodies).

1. Acute Hemolytic Reactions: (intravascular)

Incidence: 1: 33 000 transfusions.

Cause: ABO blood incompatibility.

C/P: It is usually **severe**, the severity depends on the amount of incompatible blood given. If the amount of incompatible blood given is <5% of total blood volume, the reaction is usually not severe.

a. In awake patients:

Chills, fever (cytokine related), nausea, and chest and flank pain.

b. In anesthetized patients:

Unexplained fever, unexplained tachycardia, hypotension (2ry to bradykinin, mast cell histamine, and serotonin), **intravascular hemolysis** and hemoglobinuria (2ry to complement activation), and diffuse oozing in the surgical field.

c. Lastly

DIC (due to substances released by the hemolyzed cells), shock, and renal shutdown.

Diagnosis: ABO-Rh testing and cross matching.

Management:

1. **Once a hemolytic reaction is suspected, stop the transfusion immediately.**
2. **Recheck the unit again for the blood bank slip and the patient's identity bracelet** (name and hospital number).
3. **Draw a blood sample to:**
 - * Identify **free Hb** in plasma.
 - * **Repeat compatibility testing.**
 - * Obtain **coagulation studies, platelet counts, and Hb levels** of the patient.
4. Insert a **urinary catheter** and check urine for free Hb.
5. Initiate **osmotic diuresis** with mannitol, furosemide, dopamine (low dose) and i.v. fluids to maintain UOP 1-2 mL/Kg/hr.
6. **Alkalinize the urine** to prevent precipitation of acid hematin by NaHCO₃ (one mEq/Kg i.v.).
7. **Vasopressors and inotropes** to support the BP.
8. In the presence of rapid blood loss, **platelet and FFP** transfusions are indicated.

FLUID AND ELECTROLYTE DISTURBANCES**2. Delayed Hemolytic Reactions:** (extravascular or intravascular)**Cause:**

- Formation of **antibodies** to non-D antigen of the Rh system or to foreign antigens in other systems such as the Kell, Duffy, or Kidd antigens.
- On **re-exposure** to the same foreign antigen during a subsequent red cell transfusion, **triggering** of antibody response against the foreign antigen occurs. The hemolytic reaction is typically **delayed 2-21 days after transfusion** with hemolysis of transfused donor cells.
- Pregnancy (exposure to fetal RBCs) can also cause formation of allo-antibodies to RBCs in women.

C/P: Onset **2-21 days after transfusion** which is usually mild.

* Malaise and fever.

* Decreased Hct.

* S. unconjugated bilirubin is increased due to Hb breakdown leading to jaundice and hemoglobinuria.

Diagnosis: By anti-globulin (coombs) test.

Management: Supportive.

2) Non-Hemolytic Immune Reactions:

They are primarily due to sensitization of the recipient to the donor's WBCs, platelets or plasma proteins.

1. Febrile Reactions: (1-3%)

- Due to WBC sensitization (antibodies against them in HLA system).
- There is an increase in temperature ($> 1^{\circ}\text{C}$) without evidence of hemolysis.
- To decrease this reaction, patients with a history of febrile reactions should receive **white cell-poor RBC transfusion** only with the use of i.v. sets with **20-40 μm filters** to trap most of the WBC contamination.

2. Urticarial Reactions: (1%)

- Due to plasma protein sensitization.
- There is erythema, hives and itching without fever.
- To decrease this reaction, **packed RBCs** should be used.
- It is treated with antihistaminic drugs (H_1 and H_2 blockers).

3. Anaphylactic Reactions:

- Due to Ig A – containing blood transfusion when transfused to Ig A- deficient patients who contain anti-Ig A antibodies in their serum.
- There is a picture ranging from mild to severe anaphylactic shock even if only a few millimeters of blood are given.
- To decrease this reaction, patients with Ig A deficiency should receive **washed packed RBCs**.

Either * Deglycerolized frozen RBCs.

* Ig A free blood units.

- It is treated with epinephrine, fluids and corticosteroids.

4. Non-Cardiogenic Pulmonary Edema (Adult Respiratory Distress Syndrome), Transfusion Related Acute Lung Injury (TRALI): (1:5000 unit)

- Due to transfusion of anti-leukocyte or anti HLA antibodies that interact with and cause the patient's WBCs to aggregate in the pulmonary circulation leading to damage of the alveolar capillary membrane.
- There is an acute onset (< 4 hours after transfusion) of severe hypoxemia, bilateral non-cardiogenic pulmonary edema, shock, and fever.

- It is treated with respiratory and circulatory support. The patient recovers within 48-96 hours.

5. Graft – Versus – Host Disease:

- Cause: It occurs in **immune-compromised patients** as cellular blood products contain **T-lymphocytes** which are capable of mounting an immune response against the compromised (recipient) host.

- There is fever, hepatitis, diarrhea, pancytopenia or bone marrow depression.

- To decrease this reaction, irradiation of RBCs, granulocytes and platelets transfusion are needed to effectively inactivate lymphocytes.

6. Post-Transfusion Purpura:

- Due to the development of **platelet allo-antibodies**.

- There is thrombocytopenia occurring 1 week after the transfusion.

- To decrease this reaction, plasmapheresis is generally recommended.

7. Immune Suppression:

- Due to WBCs which stimulate immunologic suppressor cells or inhibit immunologic effector cells.

- There is * Improvement of graft survival in renal transplant recipients who received preoperative blood transfusion.

* Increased cancer recurrence rates in cancer patients who received blood transfusion.

* Increased incidence of infection and sepsis after blood transfusion.

Q: What are the causes of respiratory distress and hypoxemia after blood transfusion?

A: 1. Fluid overload especially in old age patients with CHF.

2. Allergic reactions as acute hemolytic reaction and anaphylactic shock.

3. Transfusion related acute lung injury (TRALI).

Q: Discuss delayed non-hemolytic transfusion reaction?

*A: 1. Immune: * Graft versus host disease.*

** Post-transfusion purpura.*

** Immune suppression.*

*2. Non-immune: * Iron overload as deposited in vital organs in chronic patient with hemolytic anemia.*

B. Non-Immune Complications:

1) Complications of Massive Blood Transfusion:

Definition: (of massive blood transfusion)

- Replacement of the **patient's total blood volume** (> 10 units) **within a 24 hour period**.

N.B.; Transfusion of > 50% of the patient's blood volume within a shorter period e.g. 5 units in less than 1 hour is also considered massive.

Complications:

1. Dilutional Coagulopathy:

- Due to dilution of **platelets** (dilutional thrombocytopenia) or dilution of **coagulation factors** (more rare) as after one blood volume is transfused.

- Treatment:

Platelets and FFP transfusions are needed.

2. DIC and Fibrinolysis:

- Due to shock and its accompanying **tissue ischemia**, **acidemia** and waste product accumulation which occur with transfusion of blood deficient in coagulation factors. So, early treatment of shock is mandatory.

3. Citrate Toxicity:

- Due to citrate preservatives in blood and FFP units (the later contains more) that bind Ca^{++} resulting in **hypocalcemia** which in turn prolongs the QT interval with little effects on cardiac performance. It can occur in normal patients especially;

FLUID AND ELECTROLYTE DISTURBANCES

- When transfusion rate exceeds one unit/5 minutes.
 - **Hepatic disease** because citrate metabolism is mainly hepatic.
 - **Hypothermic** patients because citrate metabolism is reduced.
 - Treatment: Ca^{++} infusion during massive transfusion.
- Some give Ca^{++} **gluconate 10%**, 10 mL for each **2 units of blood** routinely. This is better after laboratory documentation of hypocalcemia.

4. Hypothermia:

- Due to massive blood transfusion of **cold banked blood** that causes;
 - * Ventricular arrhythmias up to VF when the body temperature is close to 30°C.
 - * Platelet dysfunction.
 - * Decreased citrate and lactate (and other drugs) metabolism.
- Therefore, It is recommended to warm all fluids (including blood) by a warming device up to body temperature (37°C).

5. S. K^+ Concentration Disturbances:a- Hyperkalemia: (In old blood)

- Due to massive transfusion of **stored whole blood**.
- Because the K^+ levels increase about 1mEq/L/day in stored whole blood. Plasma K^+ concentrations of stored whole blood range between 5-32mEq/L.
N.B.; A unit of packed RBCs contains insignificant amounts of K^+ because most of the plasma is removed.

b- Hypokalemia:

- Due to • Citrate which is metabolized to HCO_3^- in the liver causing metabolic alkalosis which in turn increases K^+ uptake by the recipient's cells resulting in decreased s. K^+ .
- The transfused RBCs that take up K^+ decreasing s. K^+ .

6. Acid Base Disturbances:a- Metabolic Acidosis: (In old blood)

- Due to the **acidic pH of stored blood (6.8)**. In addition to the acidosis that accompanies shock. There is usually no need to treat acidosis by HCO_3^- infusion but, if it persists NaHCO_3 is needed.

b- Metabolic Alkalosis:

- Due to the **citrate from stored blood** and the **lactate from lactated ringer solution** used during the resuscitation of shock. They are metabolized to HCO_3^- leading to metabolic alkalosis.

7. Impaired Hb Function: (theoretic possibility) (In old blood)

- Due to the decreased 2, 3-diphosphoglycerate (2, 3-DPG) levels in banked old blood which shifts the oxygen-Hb dissociation curve to the left which in turn increases O_2 affinity to Hb especially if stored > 5 days. This it is not proved to produce side effects clinically.

2) Complications of Transfusion of Old Blood:

It is an un-physiologic solution due to:

- * pH = 6.6 – 7.2.
- * S. $[\text{K}^+] = 5 - 32$ mmol/L.
- * Temperature = 2 – 6 °C.

Complications:1. Coagulopathy:

- Due to - There are no functioning platelets (only 5-10% of normal activity).
 - Factor V and VIII are 10% of the normal (labile factors).
 - Factor IX is 20 % of the normal.

Other factors are stable.

2. Micro-embolization:

- Due to blood components which tend to micro-aggregate e.g. Platelets, WBCs and RBCs.

- They are very small to be removed by the standard 170 micron blood filters. So; smaller filters are developed to remove these particles as **20-40 micron filters**, but on using these filters the rate of transfusion is dramatically decreased due to the increased resistance of the filters.

- It is claimed that these micro-aggregates may cause pulmonary dysfunction, but this has never been proven.

3. Hyperkalemia: as above in massive blood transfusion.....

4. Metabolic Acidosis: as above in massive blood transfusion.....

5. Impaired Hb Function: as above in massive blood transfusion.....

3) Infection:

1. Viruses:

• Hepatitis (B and C):

- Incidence after blood transfusion is;

1: 200 000 / transfused blood unit for B virus (in some authors it is 63 000/ transfused unit).

1: 3300 / transfused blood unit for C virus (i.e. about 90% of cases due to HCV).

• Acquired Immune Deficiency Syndrome (AIDs):

- Incidence is 1:450 000-660 000 / transfused blood unit.

- The virus is called Human Immunodeficiency Virus type I (HIV-1).

Another virus was discovered called HIV-type II (HIV-2).

- Blood is tested for HIV-1 antibodies which appear after 6-8 weeks of infection. So, infectious units may be undetected. Nowadays, they test HIV-1 antigen (and PCR-based testing for hepatitis C) so; they can detect 25% of the infectious units during this **window period or gap** (i.e. the period between viral infection and its detection by tests for the antibodies).

Some centers now also test against HIV- 2.

• **Cytomegalovirus (CMV):** It is the most common immuno-viral agent.

• **Epstein-Barr Virus (EBV).**

• **Human T cell lymphotropic virus type I:** It causes leukemia.

Human T cell lymphotropic virus type II: It causes lymphoma.

2. Parasites:

- Malaria.

- Toxoplasmosis.

- Chagas' disease.

3. Bacteria:

- Both, gram +ve (e.g. staphylococcus) and -ve (e.g. citrobacter) rarely present due to contamination.

Alternative Strategies for Ordinary Blood Transfusion

A. Autologous Transfusion:

Definition: It is the collection and re-infusion of the patient's own blood or blood components (i.e. the patient uses his own blood).

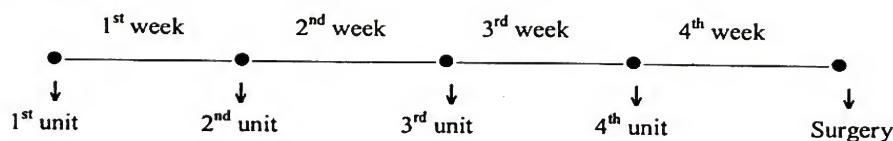
Advantages: no risk of - Transmission of AIDS, hepatitis.....etc.

- Transfusion reaction and auto-sensitization.

Types:

1. Preoperative Autologous Donation (PAD):

It is useful in elective surgeries (not emergency).

FLUID AND ELECTROLYTE DISTURBANCES**a. Donation of 3-4 Units of Blood in the 4-5 Weeks Before Surgery:****- Technique:**

- * Collection is usually started 4-5 weeks before the procedure.
- * The patient is allowed to donate a unit as long as his/her **hematocrit** is at least **34%** or his/her **Hb** at least **11 gm/dL**.
- * A **minimum of 72 hours** are required between donations to make certain that the plasma volume returns to the normal.
- * With **iron supplementation and recombinant erythropoietin** therapy (400 units weekly), 4 units can usually be collected before surgery.

- Disadvantages:

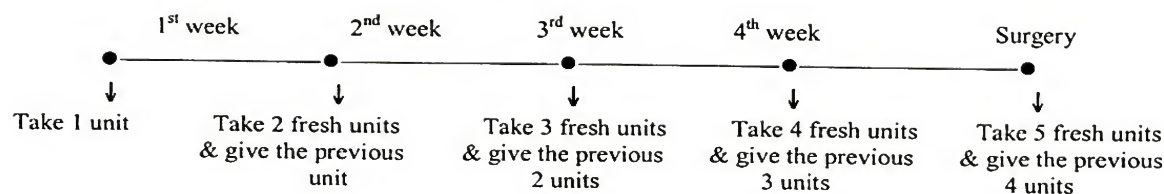
1. Errors in collections and labeling, contamination, and improper storage.
2. Allergic reactions (due to allergens e.g. ethylene oxide that dissolve in the blood from collection and storage equipment).
3. High cost.

b. Donation of 1-2 Units of Blood Immediately Before Surgery:**(Normovolemic Hemodilution Method)****- Technique:**

- * 1-2 units of blood are removed from the patient immediately before or after induction of anesthesia.
- * Then this volume is replaced by colloids or crystalloids (i.e. hemodilution) to keep the patient normovolemic, but with a hematocrit of 21-25%.
- * So, during surgery, the blood lost contains fewer RBCs and clotting factors due to the hemodilution.
- * Care should be taken during anesthesia as hemodilution may cause dilutional coagulopathy.
- * The removed blood is stored in CPD bags at room temperature up to 6 hours to preserve the platelet functions and then is given back to the patient intra- or postoperatively when needed.

- Advantages: (over PAD)

- Low cost as the blood is collected and stored at room temperature.
- More patient's convenience as minimal preoperative preparation.
- Decreased risk of human errors.

c. Donation of 3-4 Units of Fresh Blood:

- * Take one unit of blood from the patient then after one week take 2 units and give the patient back his old unit. Then after another week give him/her 2 previously taken units and take 3 fresh units and so on till the time of surgery.

2. Blood Salvage and Reinfusion (Blood Recovery and Reinfusion) (Intraoperative Auto-Transfusion):

- For cardiac and major reconstructive vascular surgeries.

- Technique:

* The shed blood is aspirated intraoperatively with an anticoagulant (heparin) into a reservoir.

* After a sufficient amount of blood is collected, the RBCs are concentrated and washed to remove debris, anticoagulant, then they are re-infused to the patient.

* It usually has a hematocrit of 50-60%.

* The post-transfusion survival of perioperative salvaged RBCs is the same as that of allogenic RBCs.

- Contraindications:

1. Septic contamination of wounds.

2. Presence of old hemolyzed blood.

3. Use of collagen or hemostatic materials.

4. Malignancy for fear of re-infusion of malignant cells to the patient, but;

• The use of leukocyte depleting filters (which is narrow).

Or • Irradiation of blood.

Both allow the use of these devices in malignancy.

5. Obstetric surgery for fear of reinfusion of amniotic fluid into the patient, but;

• The usage of leukocytes depleting filters (which is narrow) allows the usage of these devices in obstetric surgeries.

- Disadvantages:

1. Citrate over-dosage may occur.

2. Air embolism may occur.

3. Hemolysis may occur due to centrifugation.

4. Bleeding as DIC may occur due to; • Cellular debris.

• Anticoagulant over-dosage.

• Loss of coagulation factors and platelets

3. Intraoperative Plasmapheresis:

- Recently, a plasma-collection system is developed to salvage up to 100 ml of platelet-rich plasma. This technique does not cause hemodilution so it can be used in all patients including those with anemia.

- The platelet-rich plasma can be stored at room temperature until it is transfused. It is better to be placed on a rocker until its infusion and its pH be held constant.

4. Plateletpheresis:

- It can be also used.

5. Erythrocyta-pheresis:

- It is the collection of RBCs by a process similar to plasmapheresis, done 3 weeks before surgery. It is more convenient and cost effective to the patient.

B. Donor-Directed Transfusions:

- Patients can request donated blood from family members or friends known to be ABO-compatible.

- Studies comparing the safety of donor-directed units to that of random donor units have found either no difference or that blood bank units are safer.

Jehovah's Witnesses

- They object to the administration of blood and blood products for any indication for religious reasons.
- These patients should sign a waiver that relieves the physicians in court of the responsibility for any consequences of blood refusal.

Management of Blood Loss:

1. Blood is **replaced by i.v. fluids** as crystalloids, and colloids e.g. hetastarch, dextran.....
2. Technique of acute normovolemic hemodilution and intraoperative blood salvaging.

N.B.; **Blood substitutes = Plasma substitutes + RBC substitutes.**

- **Plasma substitutes** include colloids, crystalloids, and perfluorocarbons. They replace the plasma regarding the volume.
- **RBC (Blood) substitutes** include Hb solution, artificial cells, and perfluorocarbons. They replace the RBCs regarding the O₂ carrying capacity.

Artificial Blood Substitutes

(Red Cell Substitutes, Oxygen Carriers)

Oxygen Carriers is a better name for these substitutes as they lack coagulation, immune function, nutrition, and plasma proteins.

Types:

A) Hemoglobin Solutions (Stroma Free Hemoglobin):

First trials were started in humans in 1940s.

Idea:

Hb (tetramers) liberated from RBCs (e.g. during hemolysis) dissociates into monomers and dimers consisting of α and β chains. These smaller subunits of Hb are characterized by;

- They are filtered by the kidneys which decrease their intravascular half-lives and produce renal damage because they precipitate in the ascending limb of Henle.
- They are extravasated.
- They act as nitric oxide scavengers so, Hb solutions have a vasoconstricting effect.
- They increase the osmotic pressure of plasma about 3 times leading to hypervolemia.
- They have a high O₂ affinity so, the P₅₀ is decreased from 26-28 mm Hg i.e. normal to 12-15 mm Hg due to;
 - Loss of 2, 3 DPG which is a modulator of O₂ affinity.
 - Loss of acidic pH (inside RBCs) which usually decrease the O₂ affinity and shifts the O₂-Hb dissociation curve to the right.
 - The O₂ binding co-operability of Hb is lost in the dimeric and monomeric forms.
- The disrupted fragments of RBC walls cause;
 - Nephro-toxicity.
 - Interference with coagulation.
 - Activation of complement cascade.

Hb Solutions are 2 Types:

1- Ultra-structural Modification of Hb Solution:

These methods try to change Hb from dimers and monomers (with the above side effects) to tetramers (figure 33-2) by;

1- **Cross-linking** (i.e. between the 2 α and the 2 β) e.g. di-aspirin cross-linking.

Polymerization (i.e. formation of fumerate bridges between α molecules) e.g. O-raffinose polymerization.

Conjugation (i.e. Hb is linked to a soluble non-Hb polymer),

Or **formation of Microspheres** (i.e. Hb molecules are exposed to a high intensity ultrasound which creates shells of about one million Hb molecules cross linked by the superoxides formed during the sonication process).

2- **Ultra-purified Hb** to remove RBCs wall parts.

3- **Recombinant DNA technique:**

Advantages: - No need for cross-matching.
 - Does not transmit diseases.
 - Does not become rapidly outdated.

Disadvantages: - Its Hb has **low O₂ affinity**.
 - The residue of micro-organism membranes act like **endotoxins** and cause a **toxic shock syndrome**.

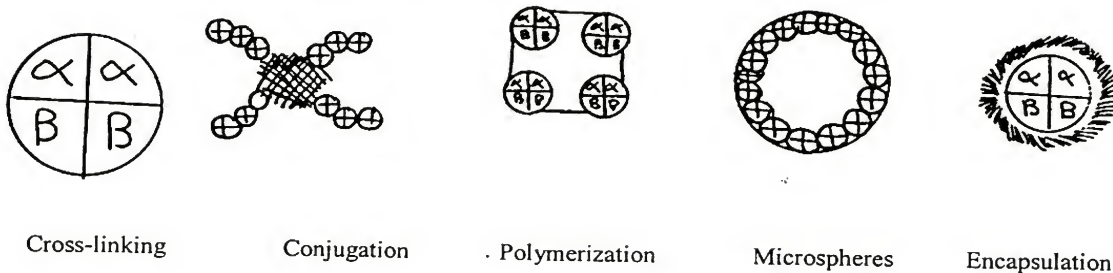


Figure 33-2; Different forms of Hb solution

General Characteristics:

- * They are kept frozen with shelf lives up to one year.
- * They are taken up and broken-down by the reticulo-endothelial system (RES) so their circulation **half lives \approx 6-8 hours**.

2- Artificial Blood Cells:

It is introduction of Hb into a cell-like structure i.e. **encapsulated Hb** (structure similar to RBCs cell wall) which makes O₂ affinity as that of normal RBCs. These coating structures are:

a- Liposomes:

Hb is coated with a **phospholipid bilayer and cholesterol**, so called liposomes (**pseudo-erythrocyte**) therefore, the $\frac{1}{2}$ life is **24 hours**.

b- Nanocapsules:

Hb is coated with a material formed of **polylactide**, so its $\frac{1}{2}$ life is **7 days**.

It is also possible to manipulate the O₂ binding /unbinding characteristics by;

- Addition of 2, 3 DPG or inositol hexaphosphate to the membrane of the artificial blood cells so they have more O₂ carrying capacity.
- Maintaining the tetrameric structure because Hb subunits exhibit co-operability.
- Addition of catalase and superoxide dismutase (both are enzymes normally present in RBCs) for radical scavenging.
- Addition of glyco-proteins (erythropoietin) for treatment of acute and chronic anemia.

Functions of Hb Solutions: (Surgical, trauma, cardiac)

- 1- They can restore circulating blood volume
- 2- They can provide adequate tissue oxygenation because they have a high O₂ carrying capacity.

Side Effects of Hb Solutions:

The maximum harmful dose is still not known.

1- Immune Suppression:

- Repeated transfusions;
- Decrease the phagocytic activity of macrophages leading to sepsis.
 - Increase the antibody titre.

FLUID AND ELECTROLYTE DISTURBANCES**2- Nephro-toxicity:**

RBC membranes in Hb solutions may cause acute renal failure.

3- Coagulopathy:

RBC membranes in Hb solution interfere with coagulation.

4- Free Radical Production:

The artificial RBCs increase superoxide ions due to the absence of reductase enzymes.

5- Vasoconstriction:

Hb dimers and monomers cause; • Inactivation of nitric oxide.
• Increasing the level of endothelin.
Both cause VC.

6- Neuro-toxicity:

NO has a neuro-protective action especially in ischemic brain tissues due to its VD action, but with the use of artificial blood there is an increase in the infarction size due to the decreased NO.

7- It interferes with the laboratory assay:

It impairs standard colorimetric laboratory spectro-photometric assays of the liver enzymes, amylase, bilirubin and electrolytes because their assays depend on presence of clear plasma.

B) Perfluorocarbons (PFC):**Idea:**

They are synthetic simple (8-10 carbon atoms) organic liquid compounds in which all H atoms are replaced by halogens (fluorine, bromine or iodine).

General Characteristics:

- They are **clear, colorless and odorless** liquids.
- They are **immiscible in water** so they should be **emulsified** before i.v. use.
- They are **biologically inert** so, they do not undergo significant metabolism (due to the strong fluorine carbon bonds).
- **Their clearance** is by; - Vaporization via the **lungs and the skin**.
- Taking up by the **RES**.

So; its $t_{1/2}$ is \approx **12-24 hours**.

These substances are not water soluble so they cannot be metabolized or excreted unchanged by the kidneys.

The selection of an appropriate fluorocarbon is dependent on its vapor pressure. The critical value is around 40 mm Hg. Vapor pressures of 50 mm Hg or more causes death in mammals from massive gas emboli. Vapor pressures of below 30 mm Hg results in prolonged elimination from the body.

- They have a **very low viscosity** because they are far smaller than RBCs so, they are likely to flow around occlusions that obstruct the blood flow of RBCs e.g. during sickle crisis and vascular diseases.
- They have a **high ability to dissolve O₂ (CO₂ and N₂O) rather than binding of O₂** molecules as Hb does. So; they can be used as a blood substitute. **Solubility coefficient of O₂ in PFC is 0.04-0.06** i.e. PFC can dissolve 0.04-0.06 mL of O₂ when the O₂ tension is 1 mm Hg while solubility coefficient of O₂ in the plasma is 0.003 i.e. the plasma can dissolve 0.003 mL of O₂ when O₂ tension is 1 mm Hg.
- They are **high density compounds** which can displace the proteinaceous exudate filling the alveoli causing alveolar recruitment and inflation.
- **Surfactants are employed in the liquid to:**
 - Decrease the surface tension of alveoli causing alveolar recruitment and inflation that improves pulmonary compliance.

- Maintain small size particles of the liquid thus enabling higher PFC concentrations and a higher surface area for O₂ exchange. It is sometimes called **Liquid or fluid PEEP**.

Types:

1- First Generation Product: e.g. Fluosol-DA.

- It is **stored frozen** and thawed out immediately before use.
- It has only **20% emulsified fluorocarbon by weight** (i.e. 20% weight: volume of solution), thus it has a **limited O₂ carrying capacity**.
- Its maximal dose is 40 mL/kg.
- It was **withdrawn from the market** in the USA.

2- Second Generation Product:

e.g. **Perfluoro-octyl-bromide (perflubron) (Oxygent™)**.

- It is an 8 carbons molecule completely saturated with fluorine atoms except for a single terminal bromine atom (C₈F₁₇B).
- It utilizes **egg yolk phospholipids** as an emulsifier so it has a **high stability** when refrigerated at 4 °C with a long shelf life for > 4 years.
- It has **90% emulsified fluorocarbon by weight**, thus has a **high O₂ carrying capacity and solubility**. It dissolves 50% O₂ when equilibrated with 100% O₂. The extraction ratio of O₂ from PFC is much higher than from Hb solution and artificial RBCs.

Uses:

1- **As a blood substitute** (as fluid volume resuscitation and to improve oxygenation): In; • **Trauma patients** e.g. emergency room, military field.....etc.

- **Perioperative blood loss.**
- **Severe anemic patients.**
- **Patients who are unable or unwilling to receive blood transfusion.**

2- Perioperative Hemodilution:

- **Preoperative blood donation** in elective surgeries.
- **Perioperative hemodilution for ischemic tissues:** PFC increase O₂ delivery to ischemic tissues as they support the microcirculation due to their low viscosity.

3- As liquid ventilation in the treatment of ARDS:

Mechanism of Action:

- **Alveolar recruitment** due to their high density that decreases the alveolar and peak airway pressures.
- PFC eliminate the air-fluid interface in the surfactant deficient alveoli. This **decreases the pulmonary surface tension, improving pulmonary compliance** and decreasing the work of breathing.
- PFC allows **redistribution of pulmonary blood flow (perfusion)** when they fill the unventilated alveoli. This **decreases the intrapulmonary shunt**, improving oxygenation.
- PFC have an **anti-inflammatory action**.

4- As a solution in extracorporeal circulation:

The low viscosity of these solutions is ideally suited for the synthetic vessels e.g.

- Hemodialysis.
 - Cardiac bypass.
 - Extracorporeal membrane oxygenator (ECMO).
- 5- **As PFC can supply O₂ to the tissues:** so it is used in;
- **Preservation of organs** waiting for transplantation.
 - **Cell cultures.**
 - **Cancer therapy** as hypoxic tumors are resistant to chemo- and radio-therapy so, by increasing the O₂ supply to them, the treatment could be improved.

FLUID AND ELECTROLYTE DISTURBANCES

- **Wound healing** as it increases healing.
 - **Carbon monoxide poisoning.**
 - 6- **As PFC can increase the transport of nitrogen (and other gases):** The solubility of nitrogen in PFC is 10 000 times its solubility in plasma. So, it is used in;
 - **Prevention of venous air embolism** (also CO₂ and N₂O emboli) e.g. during CP bypass.
 - **Decompression sickness.**
 - 7- **As an emulsifier:** in parenteral nutrition.
 - 8- **Hypotension of septic shock** as PFC inactivates NO that is responsible for hypotension in these patients.
- Adverse Effects of PFC:**
- 1- Allergy especially with Fluosol-DA.
 - 2- Bleeding tendency as they decrease the platelet count.
 - 3- They increase the liver enzymes.
 - 4- I.v. route causes;
 - Acute RVF due to multiple pulmonary platelet microemboli.
 - Perfluorocarbon foam formation.
 - Pulmonary hemorrhage.
 - Permeability pulmonary edema.
 - 5- They are taken up by the RES which results in mild symptoms that are either;
 - Early: as headache and lower backache.
 - Delayed (2-12 hours) as flu-like including fever, chills, and nausea.

Bloodless Medicine and Surgery **or Blood Sparing Strategies**

Methods of Decreasing Blood Loss (and Blood Transfusion) During Surgery

A) Preoperative Management:

- 1- **Preoperative Assessment:**
E.g. history of **bleeding disorders** (and family history).
- 2- **Preoperative Correction of Hb Level:** by;
 - Recombinant human **erythropoietin (EPO)**.
 - Recombinant **thrombopoietin** (recently developed).
 And/or • **Iron** therapy.
- 3- **Preoperative Blood Conservation:**
 - **Reducing the number of tests and the volume of blood withdrawn.**
 - **Careful management of anticoagulation** (congenital or drug induced) including discontinuation or substitution of drugs which affect clotting e.g. NSAIDs, anti-platelet agents, and anticoagulant in the perioperative period.
- 4- **Preoperative Autologous Donation (PAD):**See before.

B) Intraoperative Management:

I- Surgical Management:

- 1- **Meticulous Surgical Techniques for Hemostasis.**
- 2- **Electrocautery** (either mono-polar or bi-polar).
- 3- **Staged Surgery for Operations with a High Expected Blood Loss.**
- 4- **Patient Position:** Elevate the surgical site to decrease regional arterial pressure and increase venous drainage, but care should be taken for the probability of air embolism.
- 6- **The use of Tourniquet.**
- 7- **Local Vasoconstrictor** (e.g. epinephrine) Infiltration into the Wound.

8- The use of Topical Hemostats.**II- Anesthetic Management:**

- 1- The use of **controlled hypotension**.....See later.
- 2- Maintaining of **normothermia**.
- 3- The use of **blood cell salvage**.....See above.
- 4- **Normovolemic hemodilution**.....See above.
- 5- **Permissive hypotension** i.e. in active bleeding patients, avoid normalization of ABP until bleeding is controlled.
- 6- **Avoid coughing and straining** as both increase the ABP which in turn increases bleeding.
- 7- **Avoid hypoxia** as it produces VD and stimulates the sympathetic system that in turn increases the ABP.
- 8- **Avoid drugs** which increase the HR, ABP, and CA release as ether, atropine, gallamine, ketamine, and pancuronium.
- 9- **The use of drugs** as desmopressin (dDAVP), anti-fibrinolytics as aprotinin, e-amino-caproic acid, tranexamic acid in cardiac, liver and major orthopedic surgeries.
- 10- The use of **blood substitutes**.

C) Postoperative Management:

- 1- **Close monitoring** for bleeding.
- 2- **Adequate oxygenation**.
- 3- **Restricted diagnostic phlebotomies**.
- 4- **Postoperative cell salvage**.
- 5- The use of **drugs that enhance hemostasis** and **avoid drugs that decrease hemostasis** e.g. NSAIDs.
- 6- **Control of hypertension** e.g. by adequate analgesia.
- 7- Maintain **normothermia**.
- 8- Optimum **fluid and volume management**.
- 9- Tolerance of normovolemic anemia i.e. recommending the **restrictive transfusion strategy**.

CHAPTER 34

ACID-BASE BALANCE**Definitions:**

- **pH:** It is the -ve logarithm (base 10) of $[H^+]$

$$\text{Arterial } [H^+] = 40 \text{ nmol/L} = 40 \times 10^{-9} \text{ mol/L}$$

$$\text{Normal arterial pH} = 7.36 - 7.44$$

- **An acid:** A chemical substance that can act as a proton (H^+) donor.

A base: A chemical substance that can act as a proton (H^+) acceptor.

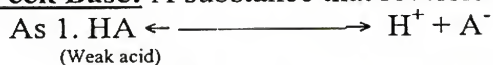
Both are Brønsted – Lowry definitions

- **A Strong Acid:** A substance that readily and almost irreversibly gives up H^+ and increases $[H^+]$.

A Strong Base: A substance that avidly and almost irreversibly binds H^+ and decreases $[H^+]$.

A Weak Acid: A substance that reversibly donates H^+ and has a less effect on $[H^+]$

A Weak Base: A substance that reversibly binds H^+ and has a less effect on $[H^+]$.



$$2. \text{ Dissociation constant (K)} = \frac{[H^+][A^-]}{[HA]}$$

[] = Plasma concentration

$$3. \quad [H^+] = \frac{K[HA]}{[A^-]}$$

4. **Henderson – Hasselbalch Equation**

$$pH = pK + \log \frac{[A^-]}{[HA]}$$

Or

$$\log \frac{\text{Dissociated anion}}{\text{Undissociated acid}}$$

- **A Buffer:**

- It is a solution that contains a weak acid and its conjugate base or a weak base and its conjugate acid (conjugate pairs) which minimizes any change in $[H^+]$ by readily accepting or giving hydrogen ions.

- From the Henderson – Hasselbalch equation, it is readily apparent that buffers are most efficient in decreasing changes in the $[H^+]$ of a solution

(i.e. $[A^-] = [HA]$ when $pH = pK$).

- **Acidosis** : It is a process that causes acids to accumulate in arterial blood.

Acidemia : It is $pH < 7.36$.

Alkalosis : It is a process that causes bases to accumulate in arterial blood.

Alkalemia : It is $pH > 7.44$.

The pH compatible with life is between 6.8 – 7.8.

Compensatory Mechanisms**1. Chemical Regulation:**

- It is the 1st line of defense against blood pH changes.
- It acts very rapidly (**within seconds**).
- It is the **least efficient** mechanism.
- It includes;

a. The Bicarbonate Buffer System ($\text{NaHCO}_3/\text{H}_2\text{CO}_3$).

- It is very important in ECF * Plasma HCO_3^- acts immediately.
- * Interstitial HCO_3^- acts within 15-20 minutes.

b. The Phosphate Buffer System ($\text{Na}_2\text{HPO}_4/\text{NaH}_2\text{PO}_4$).

- It is very important in the ICF.

c. The Protein Buffer System (Proteinic acid/Na or K Proteinate).

- It is the **most plentiful buffer** in the body as it is present in;
 - * ICF: requires 2-4 hours.
 - * Plasma proteins.
 - * Hb.

2. Respiratory Regulation:

- It is the **2nd line** of defense against blood pH changes.
- It acts within **3-15 minutes** and reaches a steady state (maximum) at 12-24 hours.
- It is a **moderately-efficient** mechanism.
- It acts by controlling the dissolved CO_2 levels in blood to keep the pH constant at 7.4.

3. Renal Regulation:

- It is the **3rd line** of defense against blood pH changes.
- It acts within a **few hours** (12-24 hours).
- It is the **most powerful and efficient** mechanism.
- E.g.: During acidosis,
 - 1- There is increased reabsorption of the filtered HCO_3^- .
 - 2- There is increased excretion of titratable acids.
 - 3- There is increased ammonia production.

During alkalosis, the reverse occurs. See renal physiology.....

The Standard Bicarbonate:

- It is not the actual bicarbonate of the sample, but an estimate of bicarbonate concentration after elimination of any abnormal respiratory contribution to $[\text{HCO}_3^-]$ i.e. an **estimate of $[\text{HCO}_3^-]$ at a PaCO_2 of 40 mm Hg.**

Base Excess (in Alkalosis) or Base Deficit (in Acidosis):

- It is the amount of acid or base that must be added to return the pH of 1 liter of blood to 7.40 at a PaCO_2 of 40 mm Hg, full O_2 saturation, and 37°C .
- It adjusts for non-carbonic (Hb) buffering in the blood.
- Simply, the base excess represents **the metabolic component of acid-base disturbances**.
- +ve values indicate metabolic alkalosis and -ve values indicates metabolic acidosis.
- The base excess is usually derived graphically or electronically from a nomogram originally developed by Siggaard-Anderson and requires measurement of Hb concentrations.

Acidosis

Physiologic Effects of Acidemia:

1. Right shift in O_2 -Hb dissociation curve, but severe acidosis causes tissue hypoxia.
 2. Hyperkalemia due to movement of K^+ out of the cells in exchange for EC H^+ .
(Plasma $[\text{K}^+]$ increases about 0.6 mmol/L for each 0.1 decrease in pH).
 3. Increased ionized plasma $[\text{Ca}^{++}]$.
 4. VD of systemic vessels decreasing the peripheral vascular resistance and causing hypotension (with reflex tachycardia) and a hyper-dynamic circulation.
- VD of cerebral vessels increases the cerebral blood flow which increases the ICP.
- VC of pulmonary vessels increases the pulmonary vascular resistance leading to pulmonary hypertension.

- | Respiratory Acidosis | Metabolic Acidosis |
|---|--|
| <p>Definition:
It is a primary increase in $\text{PaCO}_2 \rightarrow$
Decreased $\frac{\text{HCO}_3^-}{\text{PaCO}_2}$ ratio $\rightarrow \downarrow \text{pH}$</p> | <p>Definition:
It is a primary decrease in $[\text{HCO}_3^-] \rightarrow$
Decreased $\frac{\text{HCO}_3^-}{\text{PaCO}_2}$ ratio $\rightarrow \downarrow \text{pH}$</p> |
| <p>Causes: (The same causes of hypercarbia)</p> <p>(1) Alveolar Hypoventilation:</p> <ol style="list-style-type: none"> CNS depression: - Drug induced.
- Sleep disorders.
- Pickwickian syndrome.
- Cerebral ischemia or trauma. N.M. disorders: - Myopathies.
- Neuropathies. Chest wall disorders: - Flail chest.
- Kyphoscoliosis. Pleural disorders: - Pneumothorax.
- Pleural effusion. Airway obstruction:
- Upper: Foreign body, tumor or laryngeal spasm.
- Lower: Asthma, COPD, or tumors. Parenchymal disease:
- Pulmonary edema e.g. cardiac, ARDS.....
- Pneumonia.
- Pulmonary emboli.
- Aspiration. <p>(2) Increased CO_2 Production:</p> <ol style="list-style-type: none"> Large carbohydrate load (enteral or parenteral). Malignant hyperthermia. Intense shivering. Increased seizures. Thyroid storm. <p>N.B.: Acute Respiratory Acidosis:
In which plasma $[\text{HCO}_3^-]$ increases only about 1 mmol/L for each 10 mm Hg increase in PaCO_2.
An increase in PaCO_2 above 40 mm Hg, due to compensation occurs by the immediate, least efficient Hb mechanisms.</p> <p>Chronic Respiratory Acidosis:
In which plasma $[\text{HCO}_3^-]$ increases about 4 mmol/L for each 10 mm Hg increase in PaCO_2.
An increase in PaCO_2 above 40 mm Hg due to compensation occurs by the late, most efficient renal mechanisms.</p> | <p>Causes:</p> <p>(1) Increased Anion Gap:</p> <ol style="list-style-type: none"> Increased endogenous non-volatile acids: (they dissociate into H^+ and anions, their anions accumulate and replace HCO_3^- in ECF, which increases the anion gap) e.g.
- Acute and chronic renal failure.
- Diabetic and starvation ketoacidosis.
- Lactic acidosis due to hypoperfusion or non-ketotic hyperosmolar coma. Toxin Ingestion: e.g. salicylates. Rhabdomyolysis. <p>(2) Normal Anion Gap (Hyperchloremic):
I.e. the plasma $[\text{Cl}^-]$ increases to replace the HCO_3^- ions lost.</p> <ol style="list-style-type: none"> Increased GIT HCO_3^- loss:
- Diarrhea.
- Ingestion of CaCl_2 or MgCl_2.
- Fistulae (pancreatic, biliary, or small intestinal). Increased Renal HCO_3^- loss:
- Renal tubular acidosis.
- Hypo-aldosteronism. Dilutional: - Large amounts of HCO_3^- free fluids. Total parenteral nutrition (amino acid infusion). Increased intake of Cl^- containing acids.
e.g. ammonium chloride and lysine HCl. <p>N.B.: The Anion Gap (in the plasma)</p> <ul style="list-style-type: none"> - It is used for differential diagnosis of metabolic acidosis. - It is defined as the difference between the major measured cations and the major measured anions. <p>Anion gap = Major plasma cations - Major plasma anions
 $= ([\text{Na}^+] + [\text{K}^+]) - ([\text{Cl}^-] + [\text{HCO}_3^-])$ $= (140 + 4) - (104 + 24)$ $= 16 \quad \{\text{normal value} = 9-18 \text{ mmol/L}\}$</p> <ul style="list-style-type: none"> - Actually, an anion gap does not exist because electro-neutrality must be maintained in the body.
So, all plasma cations - all plasma anions = zero. <p>N.B.: - PaCO_2 decreases about 1 - 1.5 x the decrease in $[\text{HCO}_3^-]$</p> |
| <p>Treatment:</p> <p>(A) Treatment of the Cause (Decreased CO_2 production):</p> <p>Malignant hyperthermia : Dantrolene.
Status epilepticus : Muscle paralysis.
Thyroid storm : Antithyroid drugs.
Parenteral nutrition : Decrease carbohydrate intake.</p> <p>(B) Improve Alveolar Ventilation:</p> <p>Mild Cases: Bronchodilators.</p> | <p>Treatment:</p> <p>(A) Treatment of the Cause:</p> <ul style="list-style-type: none"> * Diabetic ketoacidosis: fluid + insulin + KCl. * Lactic acidosis: O_2 + tissue perfusion. * Salicylate toxicity: alkalization of urine with NaHCO_3. * Methanol toxicity: Ethanol infusion which competes for alcohol dehydrogenase. This increases formation of formic acid (toxic). <p>(B) Alkali Therapy:</p> <ul style="list-style-type: none"> - Especially if $\text{pH} < 7.20$ or $[\text{HCO}_3^-] < 10 \text{ mmol/L}$. |

<p>Respiratory stimulant (Doxapram). Diuresis (they improve lung compliance).</p> <p>- Moderate Cases: pH < 7.20 i.e. CO₂ narcosis and respiratory muscle fatigue are present. So, Mechanical ventilation is needed.</p> <p>- Severe Cases: pH < 7.10</p> <p>I.v. NaHCO₃ Increasing the inspired O₂ concentration is useful.</p> <p>N.B.; In patients with chronic respiratory acidosis e.g. COPD, try to return PaCO₂ levels to normal, but O₂ therapy must be carefully given because the respiratory drive in these patients is hypoxemia (not PaCO₂). So, correction of PaO₂ can precipitate respiratory failure (severe hypoventilation).</p>	<p>- By NaHCO₃. - Dose: 1- Empirically as a fixed dose 1mmol/Kg. 2. According to the base deficit. a. Full correction: NaHCO₃ (mmol) = BW (Kg) x base deficit (mmol/L) x 0.3 b. Half correction: (used practically). NaHCO₃ (mmol) = BW (Kg) x base deficit (mmol/L) x 0.3 x 1/2 then serial blood gas measurements are done to avoid complications as: * Overshoot of alkalosis with tetany and convulsions. * Fluid and Na⁺ overload.</p> <p>- Form: * Isotonic NaHCO₃ (1.4%) gives 163 mmol/L of HCO₃⁻. * Hypertonic NaHCO₃ (8.4%) gives 1000 mmol/L of HCO₃⁻. - Rate: especially with hypertonic NaHCO₃. Slow rates of infusion are used to decrease the side effects.</p> <p>(C) Profound or Refractory Acidemia: It is treated by hemodialysis with HCO₃⁻ dialysate.</p> <p>(D) On Controlled Ventilation: Hyperventilation should be employed to keep PaCO₂ low (30s) to correct any associated respiratory acidosis.</p>
<p>Anesthetic Considerations:</p> <ul style="list-style-type: none"> - Acidemia causes; - An increase in the depressant effects of most sedatives and anesthetic agents on the CNS and the CVS. - An increase in the non-ionized forms of opioids (weak bases) that facilitates penetration into the brain. - An increase in the depression of airway reflexes that may predispose to pulmonary aspiration. - An increase in the arrhythmogenic effects of halothane. - An increase in the S. [K⁺] so; avoid suxamethonium to prevent further increases in s. [K⁺]. 	

Alkalosis

Physiologic Effects of Alkalosis:

1. Left shift of the O₂-Hb dissociation curve causes tissue hypoxia.
2. Hypokalemia as H⁺ moves out of the cells in exchange for the movement of EC K⁺ into cells.
3. It decreases ionized plasma [Ca⁺⁺] that causes tetany.
4. Respiratory alkalosis causes;
 - VC of systemic vessels that increases systemic vascular resistance.
 - VC of cerebral vessels that decreases cerebral blood flow.
 - VC of coronary vessels that decreases coronary blood flow.
 - VD of pulmonary vessels that decreases pulmonary vascular resistance.

Respiratory Alkalosis	Metabolic Alkalosis
<p>Definition: It is a primary decrease in PaCO₂.</p>	<p>Definition: It is a primary increase in plasma [HCO₃⁻].</p>
<p>Causes: (The same causes of hypocarbia)</p> <p>1. Central Stimulation: * Pain. * Anxiety. * Ischemia. * Stroke. * Tumor. * Infection. * Fever. * Drugs as salicylates, or analeptics e.g. doxapram.</p> <p>2. Peripheral Stimulation: * Hypoxemia. * Congestive heart failure. * Non cardiogenic pulmonary edema. * Asthma. * Pulmonary emboli. * Severe anemia.</p>	<p>Causes:</p> <p>1. Chloride-Sensitive: (with NaCl deficiency and ECF depletion) * Vomiting. * Gastric drainage. * Chloride diarrhea. * Diuretics. * Cystic fibrosis.</p> <p>2. Chloride-Resistant: * Increased mineralo-corticoid activity e.g. - 1ry hyperaldosteronism. - 2ry hyperaldosteronism. - Cushing's syndrome. * Severe hypokalemia.</p>

ACID BASE BALANCE

3. Unknown Mechanisms: * Sepsis. * Metabolic encephalopathy. 4. Iatrogenic: * Ventilator-induced. N.B.; Acute Respiratory Alkalosis: - Plasma $[\text{HCO}_3^-]$ decreases 2 mmol/L for each 10 mm Hg decrease in PaCO_2 below 40 mm Hg Chronic Respiratory Alkalosis: - Plasma $[\text{HCO}_3^-]$ decrease 2.5 mmol/L for each 10 mm Hg decrease in PaCO_2 below 40 mm Hg Treatment: a. Treatment of the cause. b. For severe alkalemia ($\text{pH} > 7.55$): I.v. hydrochloric acid 0.1 mmol/L. Or I.v. ammonium chloride 0.1 mmol/L.	3. Miscellaneous: * Massive blood transfusion. * Acetate containing colloid solutions (plasmanate) * Alkali administration with renal insufficiency. e.g. Alkali therapy. * Hypercalcemia. E.g. - Milk alkali syndrome. - Bone secondaries. * Glucose feeding after starvation. N.B.; - PaCO_2 increases about 0.25 - 1 x the increase in $[\text{HCO}_3^-]$. Treatment: a. Treatment of the cause. e.g. * Loss of gastric fluid: Cimetidine b. For chloride sensitive: * I.v. saline (NaCl) and KCl. c. Severe alkalosis ($\text{pH} > 7.60$). * I.v. hydrochloric acid 0.1 mmol/L. * Hemodialysis. d. On controlled ventilation: Do hypoventilation to normalize the PaCO_2 .
Anesthetic Considerations: Alkalemia causes; • An increase in opioid induced respiratory depression due to the increased protein binding of opioids. • A decrease in s. $[\text{K}^+]$ leading to; - Severe atrial and ventricular arrhythmias. - Potentiation of non-depolarizing blockade. - Respiratory (not metabolic) alkalosis causes; • A decrease in the cerebral blood flow that causes cerebral ischemia especially if with hypotension. • A decrease in the coronary blood flow that causes coronary ischemia especially if with hypotension.	

Diagnosis of Acid-Base Disorders

Normal Blood Gas Values:

	pH	PaCO_2 (mmHg)	PaO_2 (mmHg)	Base Excess (mmol)	HCO_3^- (standard) (mmol/L)
Arterial	7.36-7.44	33-38 (40)	60-90	0 to - 2	22-28

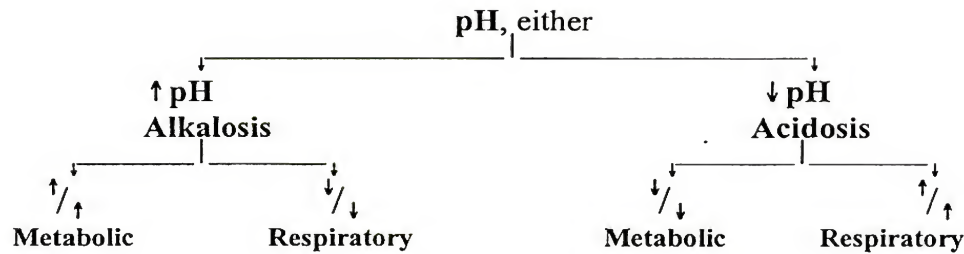
Interpretation of Blood Gas Samples

Disturbance	1ry change	Compensatory change	Expected change of compensatory response
- Respiratory acidosis * Acute * Chronic	$\uparrow \text{PaCO}_2$	$\uparrow [\text{HCO}_3^-]$	• 1 mmol $\text{HCO}_3^-/\text{L}/10$ mm Hg increase in PaCO_2 • 4 mmol $\text{HCO}_3^-/\text{L}/10$ mm Hg increase in PaCO_2
- Respiratory alkalosis * Acute * Chronic	$\downarrow \text{PaCO}_2$	$\downarrow [\text{HCO}_3^-]$	• 2 mmol $\text{HCO}_3^-/\text{L}/10$ mm Hg decrease in PaCO_2 • 2.5 mmol $\text{HCO}_3^-/\text{L}/10$ mm Hg decrease in PaCO_2
- Metabolic acidosis	$\downarrow \text{HCO}_3^-$	$\downarrow \text{PaCO}_2$	• PaCO_2 decreases 1.0- 1.5 x the decrease in $[\text{HCO}_3^-]$
- Metabolic alkalosis	$\uparrow \text{HCO}_3^-$	$\uparrow \text{PaCO}_2$	• PaCO_2 decreases 0.25- 1 x the increase in $[\text{HCO}_3^-]$

N.B.; There is no over-correction or compensation in the acid-base balance.

Steps of Interpretation of Blood Gases:

(1) Look at



(2) Look at

HCO_3^- & CO_2
to determine
 $\frac{\text{HCO}_3^-}{\text{CO}_2}$ ratio
to detect the 1ry change

N.B.; If the pH is normal, this may be;

- A normal acid base balance (the other values will be also normal).
- A compensated change (the other values will be abnormal).

(3) Determine either **simple** (i.e. there is one 1ry change and one 2ry change) OR **mixed** (i.e. there are two 1ry changes and two 2ry changes) change:

- Calculate the **rate of the change** of HCO_3^- and CO_2 .
 - If it is as expected, it is a simple change.
 - If it is **not as expected**, it is a **mixed change**.
- Look at the **direction of changes** of HCO_3^- and CO_2 levels.
 - If it is in the same direction, it is either simple or mixed.
 - If it is in the **opposite direction**, it is a **mixed change**.

(4) If there is **metabolic acidosis**, calculate the **anion gap**.

Example:

AB gas analysis shows

PaCO_2 =	11 mmHg	Hb =	9.5 gm/dL
pH =	7.47	$[\text{Na}^+]$ =	135 mmol/L
PaO_2 =	209 mmHg	$[\text{Cl}^-]$ =	95 mmol/L
Calculated $[\text{HCO}_3^-]$ =	7.7 mmol/L	$[\text{K}^+]$ =	5.5 mmol/L
Base excess =	-14.6 mmol/L		

By using the previous approach

(1) pH = 7.47 i.e. it is increased which indicates alkalosis.

(2) $\frac{[\text{HCO}_3^-]}{\text{PaCO}_2}$ ratio is $\frac{1}{4}$ therefore; it is respiratory alkalosis (the 1ry change)

(3) Determine either simple or mixed:

- The rate of changes:
 - As PaCO_2 is decreased by nearly 30 mm Hg than normal (i.e. $40 - 10 = 30$ mm Hg).
 - $[\text{HCO}_3^-]$ is expected to decrease 2 mmol/L for every 10 mm Hg decrease in PaCO_2 .

I.e. $30/10 \times 2 = 6$ mmol/L.

I.e. $[\text{HCO}_3^-]$ is expected to be 18 mmol/L.

But actually $[\text{HCO}_3^-]$ is decreased much more than expected.

Therefore; it is a mixed acid-base disturbance (1ry respiratory alkalosis + 1ry metabolic acidosis)

- Direction of changes:

Both $[\text{HCO}_3^-]$ and PaCO_2 changes are in the same direction, so; the direction can not determine simple or mixed.

N.B.; Note the difference between the calculated $[\text{HCO}_3^-]$ and the $[\text{HCO}_3^-]$ expected for a pure respiratory alkalosis roughly corresponding to the base excess. The later is larger due to the low Hb concentration.

(5) Anion gap = $(135 + 5.5) - (95 + 8) = 37.5$ mmol/L i.e. high anion gap cause of metabolic acidosis.

CHAPTER 35**HYPOTENSIVE**
ANESTHESIA**DELIBERATE (ELECTIVE) HYPOTENSION****Definition:**

It is elective (induced, controlled) reduction of ABP to reach;
Mean ABP of 50-60 mm Hg or a Systolic ABP of 60-80 mm Hg.

Values:

- To decrease blood loss and so decreasing the need for blood transfusion and its risks.
- To provide a relatively dry operative field which facilitates surgery and decreases the need for cauterization and ligatures which in turn may decrease the incidence of infection.

Indications:

Evaluate the benefits versus the risks for each patient.

- 1) **Neurosurgery:** to decrease hemorrhage and decrease aneurysmal wall tension e.g. aneurysms or vascular malformations.
- 2) **Microsurgery:** as small amounts of blood may obscure the operative field e.g. middle ear and mastoid surgeries, intraocular tumors, orbital and oculo-plastic surgeries.
- 3) **Vascular and plastic surgeries:** to decrease hemorrhage and anastomotic disruption.
- 4) **Major cancer surgeries:** as bloodless fields help the clearance of tumor tissues e.g. laryngectomy, radical neck dissection, or maxillofacial tumors.
- 5) **Surgeries with massive blood loss:** e.g. total hip replacement, total cystectomy, pelvic exenteration.
- 6) **To decrease blood transfusion:** e.g. patients with rare blood groups, patients with religious beliefs refusing blood transfusion (Jehovah's witness).
- 7) **To decrease IOP:** as controlled hypotension is the most effective method e.g. lens extraction or vitrectomy.
- 8) **To decrease myocardial O₂ demand:** when O₂ supply is already compromised e.g. hypertension in patients with ischemic heart disease undergoing coronary artery bypass procedure.

Methods to Achieve Deliberate Hypotension:

Safety in hypotensive anesthesia is dependent on maintaining an adequate O₂ supply to the brain.

A) Decreasing the Intravascular Volume:

It is done by inducing controlled hemorrhage. It is a dangerous technique. It is of historical interest and not used now.

B) Decreasing the Peripheral Resistance:**1) Decreasing Baroreceptors Sensitivity:**

- It is done by **volatile anesthetic agents especially halothane**. It allows decreasing the ABP without reflex tachycardia as halothane abolishes the baroreceptor reflex that mediates the reflex tachycardia.

2) Vasomotor Center Depression:

- It is done by **all general anesthetics**. They depress the CNS including the vasomotor center.

3) Preganglionic Sympathetic Nerve Blockade ($T_1 - L_2$):

- It is done by **high subarachnoid or epidural anesthesia**.
- Mechanisms:
 - Direct preganglionic sympathetic blockade which decreases systemic vascular resistance and decreases venous capacitance tone.
 - Interruption of adrenal sympathetic nerve supply which decreases CA release.
 - Sensory blockade prevents the hemodynamic sympathetic response to pain.
 - Decreased cardiac performance occurs with high thoracic blockade.
- Significant bradycardia may occur due to un-opposed vagal activity.

4) Sympathetic Ganglionic Blockade:

- It is done by trimetaphan, hexamethonium, and pentolinium.

5) Adrenergic (Postganglionic) Blockade (α Blockers):

- It is done by phentolamine, phenoxybenzamine, and labetalol.

6) Direct Vasodilatation of Vessel Walls:

- It is done by Na nitroprusside, glyceryl trinitrate, hydralazine, adenosine and adenosine tri-phosphate.

C) Decreasing the Cardiac Output (CO):

When hypotension is produced by arterial VD, CO is maintained or even increased provided that the patient is not positioned to produce excessive pooling of blood in the capacitance vessels, but when hypotension is produced by myocardial depressants inducing volatile agents or β blockers, CO is depressed which may compromise organ blood flow and so, is best avoided.

1) Volatile Anesthetics:

- **Halothane and enflurane** decrease myocardial contractility in a dose dependent manner. They should not be used as sole agents for hypotensive techniques but can be used with other agents in low concentrations.
- **Isoflurane:**
 - It decreases peripheral vascular resistance and myocardial contractility in large doses > 2 MAC so, it can be used alone for moderate hypotensive anesthesia.
 - It does not decrease the cerebral blood flow during hypotension because cerebral O_2 consumption is markedly reduced. Therefore, **isoflurane is the drug of choice during neurosurgery** when induced hypotension is needed (in contrast to other agents as halothane, trimetaphan, Na nitroprusside, glyceryl trinitrate, and adenosine which do not maintain the cerebral blood flow).

2) β Adrenergic Blockers:

- They decrease the HR and the myocardial contractility. They are usually **not used alone**.
- They are used as premedications **before Na nitroprusside (SNP)** because;
 - They modify renin and catecholamine release in response to SNP induced hypotension so they decrease the dose of SNP.
 - They suppress the reflex tachycardia and rebound hypertension.
- Non-selective agents e.g. oral propranolol, or atenolol may increase the risk of bradyarrhythmias.
- Cardio-specific agents e.g. metoprolol are preferred.
- Esmolol is a very short acting β blocker.

3) Ca^{++} Channel Blockers:

- Nifedipine and nicardipine produce VD mainly, which decreases the peripheral resistance.
- Verapamil and diltiazem produce -ve chrono-, ino- and dromotropic effects with little vasodilating action.

General Precautions:

- 1- Experience.

HYPOTENSIVE ANESTHESIA

- 2- A true **indication** should be present and the **contraindications** should be respected.
- 3- **ABP is gradually decreased**, avoiding sudden swings in pressure, as the compensatory mechanisms in the heart and brain take time to develop. **Also ABP is gradually returned to normal** to avoid reactionary hemorrhage.
- 4- **Restrict the extent and duration of hypotension** as much as possible. Autoregulation in coronary and cerebral circulation produces VD in response to hypotension. Maximum VD occurs when MAP falls to 50 – 60 mm Hg. Further decrease in MAP parallels the decrease in the organ blood flow.

Adjuvants to Induced Hypotension:**Factors which help to decrease surgical hemorrhage:**

See beforeBloodless medicine.

Q: What are the factors that increase bleeding during surgery?

A: They can be detected from Bloodless medicine.....see before.

Anesthetic Management:**Preoperative Management:****1- Assess for presence of contraindications to hypotensive anesthesia.****a) Absolute Contraindications:**

- 1- Carotid artery stenosis and previous cerebro-vascular accident.
- 2- Uncontrolled hypertension.
- 3- Fixed CO e.g. LVF, AS, or cardiomyopathy.
- 4- Angina and myocardial infarction within the past 6 months.
- 5- Pregnancy.
- 6- Hypovolemia.
- 7- Inexperience.

b) Relative Contraindications: They need additional care.

- 1- Controlled hypertension.
- 2- Coronary artery disease due to impaired autoregulation and reduced coronary perfusion.
- 3- Respiratory diseases e.g. asthma, COPD, chest wall deformities as scoliosis or kyphosis because hypotension further decreases the arterial O₂ tension.
- 4- Insulin dependent diabetes mellitus as;
 - Ganglion blockers and β blockers should be avoided as both potentiate hypoglycemia.
 - Cerebral autoregulation may be impaired.

2- Premedications:

- Sedatives and analgesics are important to decrease the early CA response to pain and anxiety.
- Atropine is avoided as it increases the HR.

Intraoperative Management :**Monitoring:** Standard +

- **ECG using CM5 configuration or multi-lead system.**
- **NIBP at a 1 min interval.**
- **Invasive ABP is needed.**
- **Capnography:** Its value as an index of PaCO₂ is limited because the alveolar dead space increases with hypotension.
- **CVP:** if large blood loss is expected.
- **Cerebral blood flow monitoring:**
 - Analysis of cerebral electrical activity can indicate ischemia as follows;
 - a- **Increased slow wave activity of EEG and decreased evoked potential response** indicate cerebral perfusion pressure (CPP) of 50 mm Hg and CBF of approximately 20 ml/min/100gm.

b- **Flat EEG and disappearance of evoked response** indicate **CPP of 30 mm Hg** and **CBF** of approximately **15 ml/min/100gm**.

Induction:

Intubation is mandatory with;

- Avoiding the pressor response to intubation by spraying the larynx with 4% lignocaine.
- Using a non-depolarizing muscle relaxant e.g. vecuronium.

Maintenance:

O₂: N₂O (50%) + Opioids + Inhalational agents + IPPV with a muscle relaxant.

- Ensure good oxygenation by using > 50% O₂.
- Opioids are used to provide good analgesia (+ local or regional blocks are done if possible).
- Inhalational agent: Isoflurane is the best.
- IPPV: • It increases the mean intra-thoracic pressure which decreases the VR and so it decreases the CO.
 - Adjust PaCO₂ to be 30 mm Hg (4 Kpa).
- Muscle relaxants: Avoid pancuronium.

Technique of hypotensive anesthesia: is as before.....

Postoperative Management:

Close observation of the patient in the recovery room for:

- Blood loss and adequate replacement.

• **Complications of Induced Hypotension:**

1- **CNS: Cerebral ischemia** especially with:

- **Marked drop of ABP.** because autoregulation is maintained till a MAP of 50 mm Hg only.
- **Hypocapnia** because it decreases the CBF.
- **Increased ICP** especially with SNP, GTN, trimetaphan so, they are used only when the dura is opened in patients with increased ICP.

2- **CVS: Myocardial ischemia and infarction** especially with marked drops of ABP because autoregulation is maintained till a MAP of 80 mm Hg only.

3- **Renal: Renal ischemia** which causes temporary oliguria (rarely, permanent renal impairment occurs) especially with marked decrease of ABP because autoregulation is maintained till a MAP of 80 mm Hg only.

4- **Lung: The physiologic dead space increases**, if the CO decreases which may cause hypoxia due to an increased pulmonary shunt. So, O₂: N₂O should be 1: 1.

5- **Eye: Decreased IOP and retinal artery thrombosis.**

6- **Others: - Mild changes in liver function tests.**

- **Reactionary hemorrhage and hematoma formation.**
- **D.V.T.**

CHAPTER 36

PROBLEMS WITH ANESTHESIA

They include:

(I) Respiratory Problems:

1. Complications of laryngoscopy and intubation.
2. Hypoxemia.
3. Hypercapnia (and Hypocapnia).
4. Hypoventilation.
5. Pulmonary embolism.
6. Pneumothorax.
7. Aspiration pneumonia.
8. Tracheal Tug

(II) C.V.S. Problems:

1. Hypotension (and hypovolemia).
2. Hypertension (and hypervolemia).
3. Arrhythmias.
4. Heart block.
5. Myocardial ischemia and infarction.
6. Deep venous thrombosis.

(III) CNS Problems:

1. Awareness during anesthesia.
2. Delayed recovery (decreased conscious level).
3. Postoperative pain.

(IV) Nausea, Vomiting, & Regurgitation.

(V) Temperature Changes:

1. Hypothermia.
2. Hyperthermia (and malignant hyperthermia).

(VI) Adverse Drug Effect (and Hypersensitivity).

(VII) Complications of Position.

(VIII) Noso-comial Infections.

(IX) Anesthetic Accidents.

(X) Occupational hazards.

(XI) Complications of Regional Anesthesia and Fatal Spinal.

(I) Respiratory Problems:

1. Complications of Laryngoscopy and Intubation:

.....See Airway management.

2. Hypoxemia:

Definition:

- Hypoxemia occurs;

- For adults, children, and infants (older than one month), if PaO_2 is < 60 mm Hg or SaO_2 is $< 90\%$ at rest and while breathing room air.
 - For neonates, if PaO_2 is < 50 mm Hg or $\text{SaO}_2 < 88\%$.
 - PaO_2 shows a progressive decline with age.
- Mean $\text{PaO}_2 = 102 - 0.33$ (age in years) with ± 10 mm Hg standard deviation (SD).
 N.B.; Hypoxia is subnormal levels of O_2 in air, blood or tissue.

Classification of Hypoxia:

Hypoxia	Patho-physiologic Category	Clinical Example
1- Hypoxic Hypoxia	<ul style="list-style-type: none"> • Decreased P_{Barom} or decreased FiO_2 (< 0.21) • Alveolar Hypoventilation • Pulmonary diffusion defect. • Pulmonary V/Q mismatch. • Right to left shunt. 	<ul style="list-style-type: none"> • Causes of decreased FiO_2. • Causes of hypoventilation. • Causes of V/Q mismatch (except low CO causes).
2- Circulatory Hypoxia	<ul style="list-style-type: none"> • Reduced CO. 	<ul style="list-style-type: none"> • Causes of decreased CO...see later.
3- Demand Hypoxia	<ul style="list-style-type: none"> • Increased O_2 utilization. 	<ul style="list-style-type: none"> • Causes of increased O_2 utilization.
4- Hemic Hypoxia	<ul style="list-style-type: none"> • Decreased Hb content. • Decreased Hb function. 	<ul style="list-style-type: none"> • Causes of tissue hypoxia.
5- Histo-toxic Hypoxia	<ul style="list-style-type: none"> • Inability of cells to utilize O_2. 	<ul style="list-style-type: none"> • Cyanide toxicity.

Causes of Hypoxia:

Intraoperative causes	Postoperative causes
1- Decreased FiO_2: (mainly equipment) <ul style="list-style-type: none"> • O_2 supply causes as cylinder, pipeline failure, dis- or mis-connection. • Flowmeter causes as inaccurate setting or leak. • Breathing system causes as obstruction, leak, or disconnection. • Ventilator failure. • E.T.T. causes as obstruction or esophageal intubation. 2- Hypoventilation: <ul style="list-style-type: none"> • Respiratory depression in spontaneously breathing patients e.g. heavy sedatives, opioids... • Respiratory obstruction.....see later. 3- V/Q Mismatch: <ul style="list-style-type: none"> - Inadequate Ventilation: <ul style="list-style-type: none"> • Endobronchial intubation. • Pulmonary aspiration. • Atelectasis. • Pulmonary edema causing diffusion defects e.g. over-transfusion of fluids, and LV failure. • Pneumothorax. • Bronchospasm (asthma or COPD). - Inadequate Perfusion: <ul style="list-style-type: none"> • Pulmonary embolus (as gas, thrombus, amniotic fluid.....). • Low CO as congestive heart failure, myocardial infarction, dehydration..... see later. • Fallot Tetralogy and other cyanotic congenital heart diseases. 4- Increased O_2 Utilization by Tissues: <ul style="list-style-type: none"> • Malignant hyperthermia. • Fever. • Thyroid crisis. • Seizures. 	1- Decreased FiO_2: <ul style="list-style-type: none"> • Breathing room air in high altitude as O_2 content is $< 21\%$. 2- Hypoventilation: <p>The same as intraoperative +</p> <ul style="list-style-type: none"> • Residual effects of muscle relaxants. • Obstructive sleep apnea especially in obese and elderly patients. It is transient, but repeated hypoxia down to < 40 mm Hg ($\leq \text{SaO}_2$ 75%). 3- V/Q Mismatch: <p>The same as intraoperative +</p> <ul style="list-style-type: none"> • Under-ventilation of the lung bases due to pain causes atelectasis especially in the upper abdominal or thoracic surgery. • Diffusion hypoxia by N_2O. 4- Increased O_2 Utilization by Tissues: <p>The same as intraoperative +</p> <ul style="list-style-type: none"> • Postoperative shivering or restlessness.

PROBLEMS WITH ANESTHESIA**5- Tissue Hypoxia:**

Causes that shift O₂-Hb dissociation curve to the left, e.g. alkalosis, decreased PCO₂, hypothermia and decreased Hb concentration as anemia or methemoglobinemia.

5- Tissue hypoxia:

The same as intraoperative.

C/P of Hypoxemia:

1. Cyanosis.
2. Hypoxia stimulates the sympathetic system which increases the HR (HR is decreased in children), ABP, sweating, arrhythmias, tachypnea, agitation, and restlessness. If it is persistent and severe cardiac arrest may occur.
3. C/P of the cause.

Prevention: by good monitoring

Treatment: of cause.

3. Hypercapnia:**Definition:**

It is increased PaCO₂ (or end-tidal CO₂) > 40 mm Hg or 6.0 Kpa (%).
(1 Kpa = 7.6 mmHg = 10 cm H₂O)

Causes:

Intraoperative	Postoperative
1- Increased FiCO₂: (increased inspired CO ₂) (equipment causes) <ul style="list-style-type: none"> • Rebreathing due to low fresh gas flow. • Failure of CO₂ absorption by soda lime. • Accidental administration of CO₂ in inspired gas + laparoscopy using CO₂. 	1- Increased FiCO₂: <ul style="list-style-type: none"> • Accidental administration of CO₂.
2- Hypoventilation: (inadequate CO ₂ removal). <ul style="list-style-type: none"> • Respiratory depression in spontaneous breathing patients as deep anesthesia, high spinal anesthesia, obesity.... • Respiratory obstruction as increased airway resistant. 	2- Hypoventilation: <ul style="list-style-type: none"> • Respiratory depression as residual effects of opioids, anesthetics, and muscle relaxants. - Increased FiO₂ in COPD patients. - Metabolic alkalosis. • Respiratory obstruction.
3- V/Q mismatch: (increased dead space) (Anatomic, physiologic and apparatus) <ul style="list-style-type: none"> - Decreased ventilation: The same as hypoxia. - Decreased perfusion: The same as hypoxia. 	3- V/Q mismatch: (Increased dead space) The same as intraoperative.
4- Increased CO₂ Production by Tissues: The same as increased O ₂ utilization of hypoxia.	4- Increased CO₂ Production by Tissues: The same as hypoxia.

Effects: see pharmacology.....

Management: Good Monitoring + treatment of the cause.

N.B.; Hypocapnia:**Definition:**

It is a decreased PaCO₂ or (end-tidal CO₂) < 30 mmHg or 4.0 Kpa (%).

Causes:

All causes of respiratory alkalosis.

Effects:

- The same effects as alkalosis.....See acid-base balance.
- Delay onset of spontaneous ventilation at the end of anesthesia.

4. Hypoventilation:**Causes:****A) Respiratory Obstruction:****1- Equipment: (Intraoperative)**

- **Breathing system:** Valve malfunction and kinking.
- **E.T.T:** - External compression (surgical gag, manipulation, or kinking).
 - Occlusion of the lumen (secretions and blood).
 - Cuff (over-inflation or herniation).
 - Esophageal or endobronchial intubation.

2- Patient: (Intraoperative and postoperative)

- **Oropharynx:** - Soft tissue as edema from trauma, infection, and decreased muscle tone by the tongue.
 - Tumors.
 - Obstructive sleep apnea.
- **Larynx:** - Laryngospasm.
 - Recurrent laryngeal nerve palsy.
 - Edema (drug hypersensitivity, pre-eclampsia, or infection).
 - Tumors.
- **Trachea:** - Laryngo-tracheo-bronchitis.
 - Stricture (radiotherapy).
 - External compression (surgical manipulation, hemorrhage, or goiter).
- **Bronchi:** - Secretions.
 - Pneumothorax.
 - Bronchospasm.
 - Tumors.

C/P:

- a- Spontaneously breathing patients: - Partial obstruction: stridor, hoarseness....
 - Complete obstruction i.e. asphyxia.
- b- Artificially ventilated patients: - Increased airway inflation pressure.
 - Increased expiratory phase.
 - Change in the ET CO₂ wave form.

B) Factors Affecting the Ventilatory Drive: i.e. decreased RR and T.V.

- 1- Respiratory depressant drugs as volatile or i.v. agents (except ketamine).
- 2- Hypothermia.
- 3- Cerebrovascular accidents (pre-, intra- or postoperative).
- 4- Recent hyperventilation i.e. low PaCO₂.
- 5- Primary metabolic alkalosis.

C) Peripheral Factors:

- 1- Muscle weakness: - Residual neuromuscular block (the commonest).
 - Preoperative neuromuscular disease.
 - Electrolyte imbalance.
- 2- Pain especially in abdominal and thoracic incisions.
- 3- Decreased diaphragmatic movement as abdominal distension, obesity, or tight dressings.
- 4- Pneumo- or hemothorax.
- 5- Decreased compliance of the chest wall e.g. kyphoscoliosis.

5. Pulmonary Embolism.See anesthesia with respiratory diseases.

6. Pneumothorax........See anesthesia with respiratory diseases.

7. Aspiration Pneumonia.See anesthesia with respiratory diseases.

8. Tracheal Tug

Definition: Pulling down of the trachea with each inspiration.

Causes: one of the following causes or a combination of them.

- 1- Respiratory obstruction especially during the inspiration.
- 2- Severe respiratory depression e.g. deep anesthesia or over dose of opioids.
- 3- Residual effects of muscle relaxant postoperatively. It causes flaccid paralysis of the respiratory muscles. There is no respiratory obstruction. The prolonged action of the muscle relaxant maybe due to electrolyte disturbances, metabolic acidosis, undiagnosed myasthenia gravis, or hypothermia.

Treatment:

- 1- Treatment of the cause.
- 2- Respiratory support by squeezing the bag to coincide with inspiration.

(II) C.V.S. Problems:

1. Hypotension (and Hypovolemia):

Definition:

It is decreased mean ABP < 60 mm Hg or decreased systolic ABP by $\geq 25\%$ of the patient's preoperative level.

Causes: All causes of the shock produce hypotension at first, then shock occurs

Management:

Good monitoring + C/P of hypovolemiasee shock.

Treatment:

1. Treatment of the cause e.g. i.v. fluids, decreased anesthetics concentration.
2. Other measures e.g. Oxygenation, elevate the patient's leg and the head down position.
3. Drugs: vasopressors e.g. ephedrine, phenylephrine, and inotropes.

2. Hypertension (and Hypervolemia):

Definition:

It is increased systolic ABP $\geq 25\%$ of the patient's preoperative level.

Causes:

1- Coexisting Hypertension:

- Diagnosed or undiagnosed.
- Treated or untreated.
- Pheochromocytoma.
- Pregnancy-induced hypertension.

2. Increased Sympathetic Tone:

- Inadequate analgesia or anesthesia.
- Airway manipulation e.g. intubation or cough on E.T.T.
- Hypoxemia.
- Hypercapnia.

3. Drugs:

- Epinephrine.
- Ephedrine.
- Ergometrine.
- Ketamine.

4. Aortic Cross Clamping.**5. Malignant Hyperthermia.****6. Hypervolemia:** due to;

- Heart failure.
- Over-transfusion.
- Inability to excrete a fluid load e.g. **renal impairment.**
- Misleading **monitors** e.g. CVP not indicating LV dysfunction.
- Pregnancy circulatory changes at **delivery.**
- **Hypoproteinemia.**
- Water intoxication e.g. **TURP Syndrome.**

C/P of Hypervolemia:

- Facial edema and pitting edema in pre-sacral area (in bedridden patients).
and in pre-tibial area (in ambulatory patients).
- Increased HR.
- Increased ABP but ABP may be decreased if LV failure occurs especially in elderly patients.
- Pulmonary edema.
- Increased UOP.

Management:

- Good monitoring and treatment of the cause.

3. Arrhythmias.See before anesthesia with C.V.S. diseases.**4. Heart Block.**See before anesthesia with C.V.S. diseases.**5. Myocardial Infarction and Ischemia.**
.....See before anesthesia with C.V.S. diseases.**6. Deep Venous Thrombosis**... See before anesthesia with pulmonary diseases.**(III) CNS Problems:****1. Awareness During Anesthesia:****Incidence:** 0.2% for general cases.

The incidence increases in obstetric, cardiac anesthesia, and hypovolemic patients.

Types (Forms) of Patient Awareness During Anesthesia:**1. Implicit Memory:**

- It is **not accompanied by conscious recall of events.**
- The patients may display **postoperative psychic trauma** e.g. insomnia, depression, sleep disturbances, dreams, flashbacks, anxiety and fear of death. It may persist for months or years and may be uncovered under hypnosis.

2. Explicit Memory:

- It is **accompanied by conscious recall of events** (unpleasant sensations), most commonly auditory perception, visual perception, sensation of paralysis and pain.
- The patients may display;
 - **Intraoperative stress** that causes sympathetic stimulation that in turn increases HR, ABP, and sweating.
 - **Postoperative psychic trauma** e.g. insomnia, depression.....

Causes: (and factors increasing the incidence of awareness)

- 1- **Anesthetic agents** have been intentionally administered **in limited doses** e.g. to cesarian section patients, cardiac surgery and hypovolemic trauma patients.

PROBLEMS WITH ANESTHESIA

2- Machine Malfunction e.g. an uncalibrated vaporizer administering lower doses than the desired, breathing system disconnection or leaks.

3- Increased dependence on muscle relaxants so, the incidence is decreased in spontaneously breathing patients. The patient's movement remains the best premonitory sign of unwanted patient awareness.

4- Selection of short-acting anesthetic agents delivered at higher planes of anesthesia to provide quick patient recovery especially with the **increasing demand for outpatient anesthesia**.

5- Increased willingness of our patient's public to report this complication.

6- It may still occur even with taking all the above precautions.

2. Delayed Recovery (Decreased Conscious Level):

Causes:

(1) Metabolic and Electrolyte Causes:

1. **Hypoglycemia** e.g. diabetic coma.
2. **Hyperglycemia** e.g. diabetic ketoacidosis or hyper-osmotic non-ketotic coma.
3. **Hypokalemia** e.g.see causes.
4. **Hyponatremia** e.g. water intoxication as TURP syndrome.
5. **Hypoxia** e.g.see causes.
6. **Hypercapnia** (>70 mmHg) e.g.see causes.
7. **Hypocapnia** that causes hyperventilation.
8. **Renal failure** which decreases drug excretion and alters the level of consciousness.
9. **Hepatic coma** (encephalopathy).

(2) Cerebral Hypoperfusion:

Risk Factors:

- Old age.
- Atherosclerosis.
- Chronic hypertension that changes CBF autoregulation.
- Previous CNS lesions e.g. strokes, tumors or epilepsy.
- Surgery e.g. carotid endarterectomy, cardiopulmonary bypass, or intracranial procedures.

Causes:

1. **Severe Hypotension** (unintentional or elective).
2. **Severe Hypertension** that causes cerebral edema and intracerebral hemorrhage.
3. **Cerebral embolism and paradoxical air embolism** (if there is a right to left shunt).
4. **Cerebral hemorrhage**.

(3) Cerebral Depression by Drugs:

Risk Factors:

1. Hypothermia that decreases drug elimination and metabolism.
2. Old age is associated with a decreased drug elimination and metabolism.
3. Renal disease that decreases drug elimination and metabolism.
4. Liver disease that decreases drug elimination and metabolism.
5. Hypothyroidism that decreases drug elimination and metabolism.
6. Hypo-albuminemia that increases free (active) drug availability.
7. Cimetidine and β blockers decrease hepatic blood flow that decrease drug elimination and metabolism.

e.g.:

1. **Anticholinergics** (except glycopyrrolate as it does not cross BBB).
2. **Acute alcohol toxicity and abuse** as it decreases barbiturates metabolism and acts as a sedative.
3. **Benzodiazepines** (especially long acting).

4. **Opioids** (especially long acting, including large doses of fentanyl).
 5. **Barbiturates** (especially large or repeated doses).
 6. **Volatiles** (especially those with high blood/gas solubility coefficient as they have delayed removal from the body).
 7. **Muscle relaxants**.....see causes of prolonged muscle relaxant action.
 8. **Anti-parkinsonian drugs and tricyclic antidepressants:** They have anticholinergic side effects and augment the sedation produced by scopolamine.
 9. **Reserpine or methyl dopa** decrease the MAC and produce anesthetic overdoses.
 10. **Intracranial spread of LAs** after subarachnoid injection e.g. accidental subarachnoid injection during epidural block.
- N.B.; - These drugs are taken as a premedication or intraoperative or at home (with residual effects).
 - The effects of these drugs are more obvious if they are taken at the end of the procedure and no pain is present (as the pain speeds the recovery).
 - The response to physical stimulation e.g. forceful jaw thrust and the response to nerve stimulation can differentiate between somnolence and paralysis.
 - The response to peripheral nerve stimulator alone can differentiate between paralysis and coma.

Q: Discuss drug-induced coma?

A: You can estimate most of them from the above drugs.

Management:

Investigations to detect the cause e.g. CT scan for cerebral lesions.

Treatment: of the cause.

3. Postoperative Pain.

(IV) Nausea, Vomiting, and Regurgitation:

1. Vomiting:

- **It is** a reflex active expulsion of materials from the GIT via the mouth by muscle contractions.
- **Afferent fibers**: They pass through the **vagus** from many parts of the body.
- **Centers**: - **Vomiting center**: It lies at the dorso-lateral border of the lateral reticular formation.
 - **Chemoreceptor trigger zone**: It lies superficial to the vomiting center and is reflexly stimulated by chemical changes.
- **Action**: Deep inspiration followed by closure of the glottis then expiration occurs together with contraction of the muscles of the abdominal wall and descent of the diaphragm. The body of the stomach relaxes while the pylorus contracts propelling the stomach contents into the esophagus and mouth while the glottis goes into spasm during the expulsive phase, it soon relaxes rendering aspiration very likely in the unconscious supine patient.
- **Risk (Predisposing) Factors**:
 a- **Intraoperative Nausea and Vomiting**:
 • **Hypoxia**.
 • **Light anesthesia** (2nd stage) i.e. during induction or recovery, during that time reflexes are intact so, when food reaches the vocal cords, spasm of the vocal cords occurs so, the incidence of aspiration is low.
 • **Breath-holding and cough**.
 • **Irritation of the base of the tongue or the pharynx** e.g. oropharyngeal airway.
 b- **Postoperative Nausea and Vomiting**:
See day case anesthesia.

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+ **Risk factors of aspiration pneumonitis** (see anesthesia with pulmonary diseases).

- **Dangers of Vomiting During Anesthesia:**

- Inhalation of gastric contents that may cause aspiration pneumonia.
- Laryngeal spasm that causes hypoxia.
- Cardiac inhibition from reflexes originating in the bronchi.

2. Regurgitation:

- **It is** passive passage of gastric juice and contents into the esophagus and mouth. It may be silent i.e. not apparent to the anesthesiologist.

- **Risk (Predisposing) Factors:**

The same as factors of **aspiration pneumonitis** (see anesthesia with pulmonary diseases).

a- **Relaxation of the Crico-Pharyngeal Sphincter:**

- The crico-pharyngeal sphincter is at the **upper end of the esophagus** at the level of C₆ and is composed of striated muscles. Normally, it allows the passage of food and fluids from the pharynx into the esophagus. Deep anesthesia and muscle relaxants cause its relaxation and allow the passage of fluids in the reverse direction. As it occurs **during deep anesthesia** i.e. laryngeal reflexes are absent; the **incidence of aspiration is very high.**

b- **Lower Esophageal Sphincter:**

- It is an area (2-5 cm) in length of higher **resting intraluminal pressure** normally **10-15 cm H₂O**, present at the region of the cardia.

- It relaxes during esophageal peristalsis to allow passage of food into the stomach, but remains contracted at other times.

- Reflux is not related to the lower esophageal sphincter tone per se, but to the barrier pressure (difference between gastric and lower esophageal sphincter pressure)

Barrier pressure = Lower esophageal sphincter pressure – Intragastric pressure.

Drugs Affecting the Barrier Pressure:

• **Drugs increasing the barrier pressure** (i.e. they decrease regurgitation):

1. Anti-cholinesterase e.g. neostigmine.
2. α -adrenergic agonist.
3. Suxamethonium: It was thought that suxamethonium increased intra-gastric pressure during fasciculations that in turn increased reflux and regurgitation, but recently, it is clear that suxamethonium increases lower esophageal pressure greater than the gastric pressure that in turn increases the barrier pressure.

• **Drugs decreasing the barrier pressure** (i.e. they increase regurgitation):

The same drugs causing delayed gastric emptying.see aspiration pneumonitis.

1. Anticholinergics e.g. atropine.
2. Ganglion blockers.
3. Thiopentone.
4. Opioids.
5. Ethanol (alcohol).
6. Tricyclic antidepressant.

(V) Temperature Changes:

Physiology of Body Temperature:

Afferent: from receptors in the skin, neuraxis, abdominal and thoracic tissues.

Cold sensations are transmitted via **A δ fibers**, but **warm** sensations are transmitted via **unmyelinated C fibers**. They pass to the hypothalamus through the **anterior spino-thalamic tract**.

Center: Hypothalamus.

Response: • Cutaneous VD and VC.

- Sweating.
- Shivering.

1. Hypothermia:

Types:

- A) Induced (Deliberate or Intentional) Hypothermia.
- B) Accidental (Inadvertent or Unintentional) Hypothermia.

A) Induced (Deliberate or Intentional) Hypothermia:

Indications:

It is a **protective method** used to **lower** the metabolism of the body as a whole decreasing the dangers from hypoxia and **cellular damage** resulting from regional occlusion of blood flow to the brain, heart, liver, kidney and spinal cord as in:

1. **Cardiac surgery** under cardiopulmonary bypass....see cardiac surgery anesthesia.
2. **Neurosurgery** especially vascular brain tumors and cerebral aneurysm surgeries.
3. **Vascular surgery:** - **Carotid endarterectomy** for brain protection.
 - **Aortic arch aneurysm** excision for major organ protection.
 - **Descending thoracic aortic aneurysm** excision for spinal cord protection.

Degrees of Hypothermia:

- Mild hypothermia → 35-28 °C.
- Moderate hypothermia → 27-20 °C.
- Deep or profound hypothermia → < 20 °C.

Techniques:

- By Extracorporeal Circulation. **This method** is faster than surface cooling and mainly used in open heart surgery.

B) Accidental (Inadvertent, Unintentional) Hypothermia:

Definition:

It is an unintentional decrease of core body temperature to < 36°C (some authors say < 35°C) during anesthesia.

Causes:

1) Effect of Anesthesia on Core Temperature:

a- General Anesthesia:

• Drop in Core Temperature:

- **Phase I:** Core temperature usually **drops 1-2°C during the first hour** of general anesthesia **due to redistribution of heat** from the warm central compartment (e.g. abdomen, or thorax) to the cooler peripheral compartment (e.g. arms, or legs) from **anesthetic-induced VD**. This explains most of the initial drop of temperature, with heat loss being a minor contributor (figure 36-1).

- **Phase II:** Core temperature then **decreases** more gradually during the ensuing **3-4 hours** due to **continuous heat loss** which exceeds heat production as anesthesia decreases metabolism about 25%.

- **Phase III:** (Thermal plateau)

Temperature eventually reaches a point of steady state or equilibrium as **heat loss equals metabolic heat production**.

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• **Central Inhibition of Thermoregulation:**

General anesthesia produces inhibition of central thermoregulation by interfering with the hypothalamic function (i.e. decreased VC and shivering threshold and increased sweating threshold). So; the body cannot compensate for hypothermia e.g.

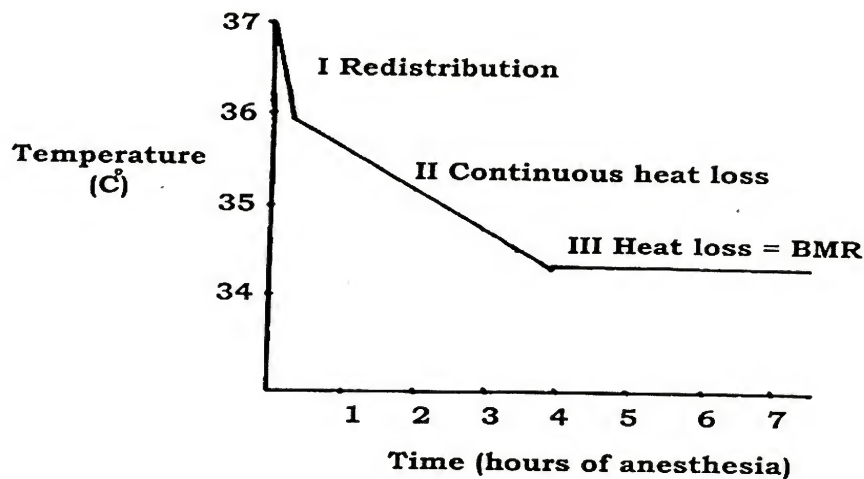


Figure 36-1; Effect of anesthesia on core temperature

N.B.;

- Normally the hypothalamus maintains the core body temperature within a very narrow range (**the inter-threshold range**; It is the temperature between which no thermo-regulatory response is initiated.). So, an increased body temperature a fraction of a degree induces sweating and VD, while a decreased body temperature triggers VC and shivering. **GA increases the inter-threshold range** from $\pm 0.2^{\circ}\text{C}$ to $2 - 4^{\circ}\text{C}$ (figure 36-2).

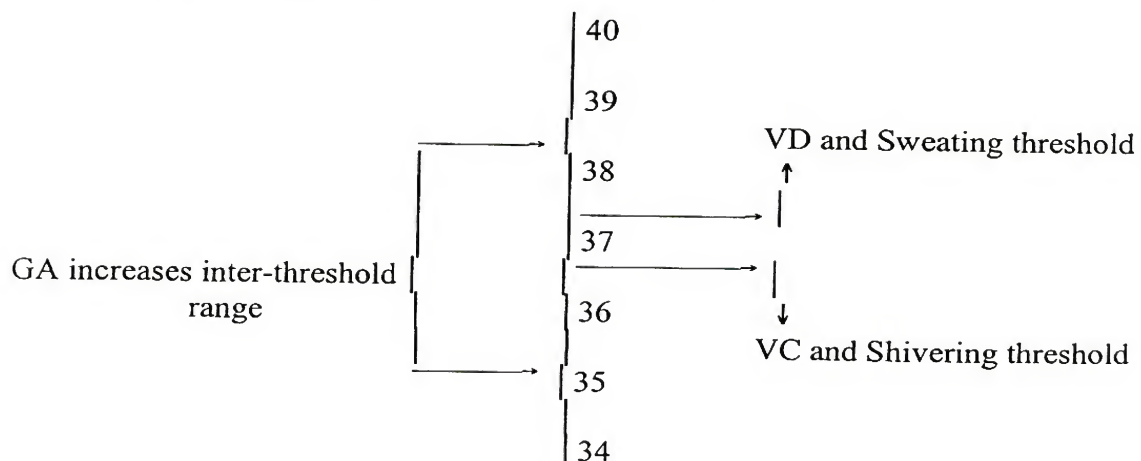


Figure 63-2

b- Regional Anesthesia (Spinal and Epidural) (not when the LAs are administered intravenously) causes;

• **Drop in Core Temperature:**

Phase I: The same as GA, but due to VD, subsequent internal **redistribution** of heat occurs.

Phase II: The same as GA, but due to heat loss produced by impaired thermoregulation caused by;

An altered perception of temperature in the blocked dermatomes by the

hypothalamus (as opposed to central drug effects seen with GA).

• **Decreased VC and shivering threshold for the area above the block.**

So, both general anesthesia and local anesthesia increase the inter-threshold range, but by different mechanisms.

2) Other Contributing Factors:

- 1- **Extremes of ages** (in geriatric patients, there is a decrease in muscle mass and in pediatric patients, there is a decrease in subcutaneous fat).
- 2- **Long duration of surgery.**
- 3- Irrigation or i.v. infusions with **cold fluids**.
- 4- **Systemic diseases affecting the muscles** because they may cause a decreased muscle mass.
- 5- Drugs: as **muscle relaxants** decrease shivering.
- 6- Heat loss by **radiation** e.g. - Cold ambient operation room temperature $< 24^{\circ}$.
- 7- Heat loss by **evaporation** e.g. - Dry cold anesthetic gas ventilation.
 - The use of wet packs.
 - Sweating.
 - Open body cavity e.g. abdominal surgeries.
- 8- Heat loss by **convection** e.g. - Higher theatre air flow rates (important).
- 9- Heat loss by **conduction** e.g. - Contact with cold objects.

Prevention of Unintentional Hypothermia:

1. **Increase ambient temperature and humidity.**
2. **Warm i.v. solutions and irrigation fluids** to at least 37°C .
3. **Enclose exposed viscera** in plastic bags.
4. **Humidify the inspired gases** by attaching a heated humidifier or an artificial heat moisture exchanger to the anesthetic circuit.
5. **Warm mattress and blanket** (more effective on top of the patients).
6. **Apply plastic wraps and swaddlings around the limbs and the head** to insulate the patient.
7. **Use low flow anesthesia.**

Physiologic Effects of Hypothermia: (↓)

(1) C.V.S:

- **HR, ABP, and CO** progressively decrease as the temperature decreases.
- **Arrhythmias** occur at body temperatures $< 30^{\circ}\text{C}$. The most common are PVCs.
- VF may occur at temperatures $< 28^{\circ}\text{C}$.
- **ECG changes that occur $< 25^{\circ}\text{C}$** are prolonged PR interval, widen QRS complex, elevated ST segment, and depressed T-wave.

(2) Respiratory System:

- **RR:** It decreases up to apnea which may occur at a temperature of 26°C .
- **O_2 availability to tissues is decreased** due to - Respiratory depression.
 - Decreased CO .
 - Peripheral V.C.
 - Increased blood viscosity.
 - Shift of O_2 -Hb dissociation curve to the left.

(3) CNS:

- **Cerebral metabolism:** Hypothermia decreases both basal and electrical metabolic requirements throughout the brain (the cerebral cortex would tolerate longer periods of hypoxia at low temperatures).
- **CBF, brain volume, and CSF pressure are decreased.**

PROBLEMS WITH ANESTHESIA

- **EEG:** shows;
 - **Depression** of electrical activity (as deep anesthesia) where there is a decreased frequency and an increased amplitude (voltage) of electrical activity (low-frequency high voltage activity). So, the MAC of volatile anesthetics is decreased.
 - **Burst suppression:** periods of isoelectricity interspersed with bursts of activity.
 - Isoelectric EEG occurs at deep hypothermia.

(4) Kidneys:

- There are decreased RBF and GFR.
- Urine formation stops around 20°C.
- **Cold diuresis:** As after profound hypothermia, water diuresis occurs.

(5) Blood:

- There is an increased blood viscosity.
- There is an increased rouleaux formation.
- There is a reversible coagulopathy: due to depressed clotting mechanisms and platelet dysfunction.

(6) Muscles: • The duration and potency of the block of muscle relaxants are increased.

- Postoperative shivering.....see later.

(7) Metabolism:

- **Depressed metabolism and O₂ consumption** occur in a non-linear relation with hypothermia
 - From 37°C-30°C, the metabolism and O₂ consumption are decreased by 7% for each 1°C drop in the body temperature.
 - Below 30°C, the metabolism and O₂ consumption are decreased by a slow down manner.

Temperature °C	37°C	30°C	28°C	25°C	20°C	10°C
O ₂ consumption %	100	50	40	25-30	20	10

- Increased protein catabolism occurs leading to **poor wound healing**.
- Decreased glucose utilization occurs leading to **hyperglycemia** during hypothermia.
- **Decreased lactic acid, citrate, and heparin metabolism** occur.

(8) Acid-Base Balance:

- **Combined respiratory and metabolic acidosis:** due to;
 - Increased CO₂ solubility.
 - Respiratory depression.
 - Increased lactic acid formation.
 - Decreased lactic acid metabolism due to suppression of the liver functions.
 - Impaired renal compensation due to suppression of the renal functions.

(9) Electrolytes:

- **K⁺:** - **Hypokalemia:** hypothermia increases cellular uptake of K⁺ (rewarming may be associated with hyperkalemia if K⁺ was given during hypothermia).
- **Hyperkalemia:** due to associated acidemia.

N.B.; The cold heart is more sensitive to the decreased s. K⁺.

- **Ca⁺⁺:** - **Hypocalcemia:** may occur if **stored blood** was transfused during hypothermia due to **impaired citrate metabolism** (So, Ca gluconate should be given with each unit of donor blood).

(10) Immunity:- It is depressed increasing the susceptibility to infections.**Postoperative Shivering**

- **It is more common** after:

- **Hypothermia** (but its onset is not related to the body temperature). It can occur with normothermia.
- **Inhalational anesthetics.**

- **Anticholinergic premedications.**
- **Females** in the **luteal**, than the follicular, phase of the menstrual cycle.

- Mechanism:

The exact mechanism is unknown

It may be related to the **alteration in the descending control of spinal reflexes** after general anesthesia. It differs from shivering due to sepsis (thermo-regulatory shivering).

- Effects:

Shivering increases the metabolic rate resulting in;

- **Increased O₂ consumption** (that may reach 5-folds) causing hypoxia.
- **Increased CO₂ production** causing hypercarbia and acidosis.

So, CO and minute ventilation are increased. That is poorly tolerated in patients with limited cardiac or pulmonary reserves.

Also, The incidence of **postoperative myocardial ischemia is increased.**

Treatment:

1. **Maintenance of normothermia** is very important in prevention and treatment.
2. **O₂ supplementation.**
3. **Meperidine i.v. 25-50 mg** (the most effective).

Chlorpromazine i.v. 10-25 mg, but it produces peripheral VD which increases the heat loss.

Or Butorphenol i.v. 1-2 mg.

These drugs may have specific actions on the temperature regulation centers in the hypothalamus. So, they prevent and treat postoperative shivering whatever the cause is.

N.B.; Treatment of shivering of sepsis and immune reaction:

By inhibitors of PG synthetase e.g. aspirin, acetaminophen, NSAIDS, and glucocorticoids.

N.B.; Types of Shivering:

- 1- Shivering due to hypothermia.
- 2- Postoperative shivering.
- 3- Shivering due to sepsis and fever.

Q: Anesthesia and temperature changes, discuss?

2. Hyperthermia:

Definition:

It is increased core body temperature $> 37.5^{\circ}\text{C}$ or increased temperature $> 2^{\circ}\text{C/hr}$.

Causes:

1- **Infections.**

2- **Immunologically mediated process:**

- Drug reactions.
- Blood reactions (incompatible blood transfusion).
- Tissue destruction (rejection).
- Connective tissue disorders.
- Granulomatous disorders.

3- **Tissue damage as;**

- Trauma.
- Acute hemolytic crisis.
- Infarction.
- Thrombosis.

4- **Neoplastic disorders.**

5- **Metabolic disorders:**

- Thyroid storm (thyroid crisis).
- Adrenal (addisonian) crisis.
- Pheochromocytoma.
- Malignant hyperthermia.
- Neuroleptic malignant syndrome.
- Acute gout.
- Acute porphyria.

6- **Drug toxicity as atropine toxicity.**

PROBLEMS WITH ANESTHESIA**Effects of Hyperthermia:**

1. It increases the metabolic rate causing the same effects of shivering.
2. Sweating and peripheral VD occur, they may cause hypovolemia and hypotension.
3. Extreme hyperthermia leads to seizures and CNS damage.

Treatment:

1. Exposure of the body surface.
2. Application of ice packs.
3. Use of fans.
4. Cold i.v. fluids.
5. Treatment of the cause.

Malignant Hyperthermia **(MH syndrome)**

It was 1st described by Denborough and Lorell in 1960.

Definition:

It is an inherited clinical myopathic syndrome affecting the skeletal muscle cells causing an **acute hyper-metabolic state**. It occurs in susceptible patients when exposed to a triggering agent.

Incidence:

Incidence of fulminant classic malignant hyperthermia syndrome (MHS) is

- 1 : 260 000 when GA is used.
1 : 60 000 when suxamethonium is used.

Aetio-Pathology:**Mode of Inheritance**

1. **Autosomal dominant** with variable expressivity where a mutation occurs in the ryanodine receptor gene of MHS which is carried on **chromosome 19** in humans.
2. Recently **heterogenous polygenic disorders** is considered i.e. presence of many genes (30 mutations) related to MHS in human e.g. on chromosome 17 and chromosome 1.

Pathogenesis:

- There is a hereditary defect in Ca^{++} binding in the **sarcoplasmic reticulum** (it is the primary focus for pathology now) in skeletal muscles and possibly in cardiac muscle cells as well with an increased phospholipase A2.

- In the presence of specific **triggering agents**, Ca^{++} is released into the cytoplasm causing an abnormal **irreversible myo-fibrillar contracture** that produces depletion of ATP and O_2 consumption. This results in **anaerobic glycolysis** that causes;

- Accumulation of lactic acid (lactic acidosis).
- Increased CO_2 production.
- Increased heat production.

I.e. **Hypermetabolic state + muscle tissue damage.**

- The muscle cell membrane stability is lost causing leakage of K^+ from the muscle cells into the ECF that leads to **hyperkalemia**.

Triggering Agents:

- Inhalational agents: (all except N_2O)
- Halothane (the most common).
- Enflurane, isoflurane, methoxyflurane, desflurane, sevoflurane.
- Muscle relaxants:

- Succinylcholine (the most common).
- D-tubocurarine.
- Other drugs:
- Phenothiazines.
- Lignocaine (especially in large doses).

Clinical Picture:

Clinical Types:

- **Rigid type** : 75% of the affected patients.
- **Non-rigid type** : 25% of the affected patients.

Clinical Features:

- **Unexplained tachycardia:** It is the earliest and the most consistent sign present in 96% of patients.
- **Hyperthermia:** It is usually $> 41^{\circ}\text{C}$, and a late inconstant sign.
- **Increased E.T-CO₂:** It is the most sensitive sign.
- **Altered ABP:** In 85% of the patients.
- **Tachypnea:** In 85% of the patients.
- **Muscle rigidity:** In 75% of the patients.
- **Cyanosis:** In 70% of the patients.
- **Masseter spasm:** In 50% of the patients who are MH susceptible.
- Arrhythmias.
- Skin mottling.
- Profuse sweating.
- Over heated CO₂ absorber.

Laboratory Findings: During the acute crisis.

- **AB gases:** - Acidosis: Respiratory or metabolic due to $\uparrow\text{CO}_2$ and lactic acid production.
- Increased PaCO₂ and decreased PaO₂.
 - **Electrolytes:**
 - K⁺ is increased then, later on, it is decreased.
 - Ca⁺⁺ is increased then, later on, it is decreased.
 - Na⁺ is decreased.
 - Mg⁺⁺ is increased.
 - **Others:** The following are **increased**;
 - Creatine phosphokinase (CPK).
 - Lactate dehydrogenase.
 - Aldolase.
 - Lactate.
 - Pyruvate.
- Myoglobin causing myoglobinuria and renal failure.

Anesthesia in Susceptible MH Patients:

Clinical Picture of Susceptible MH Patients:

1. **Family history** is +ve in 25% of cases.

There is a history of death or problems during anesthesia in relatives.

2. There are usually **musculoskeletal disorders** e.g.;

- Muscular disorders

- Bulky muscle with rounded belly.
- Atrophied or hypertrophied muscles.
- Muscular cramps.
- Strabismus.
- Myotonia congenita.
- Duchenne's dystrophy.
- Central core disease.

- Skeletal disorders

- Short, stocky stature (Kyphoscoliosis).
- Poor dental enamels.
- Pectus carniatum.
- Joint hyper-mobility with dislocations
- Osteogenesis imperfecta.
- Club foot.
- Hypoplastic mandible.

3. **King Denborough Syndrome:**

- C/P: Short stature, thoracic kyphosis, mental retardation, ptosis, low set ears and MHS.
- The only syndrome that always involves MHS.

PROBLEMS WITH ANESTHESIA

N.B.; A past history of previous uneventful halothane anesthesia does not exclude a patient's susceptibility to malignant hyperthermia because 1/3 of cases manifest during a 2nd or a subsequent anesthetic course.
N.B.; The incidence of MHS in susceptible patients is 0.4% if trigger-free anesthetics are used.

Differential Diagnosis of MHS:

A- During anesthesia: sepsis; thyroid storm, pheochromocytoma, iatrogenic overheating, or central core diseases (It is a congenital AD disease, affect proximal muscles, hypotonia at birth with muscle strength usually improves later in life leading to events similar to MH syndrome during GA).

B- Outside OR: Ionic contrast agent injected into CSF, cocaine over dosage or neuroleptic malignant syndrome.

Investigations (Confirmatory Tests) for Susceptible MH Patients:**1. S. Creatine Phosphokinase (CPK):**

It is used as a **screening test** only, but is **unreliable** as it may be normal in 1/3 of susceptible MH patients.

2. Caffeine-Contracture Test: Only done in **MH investigation centers**.

- It is **reliable in 95%** of cases and is the **most diagnostic test**.
- **Fresh muscle strip biopsy** (from quadriceps) is taken and preserved in ringer's solution to be tested in the laboratory.
- **Different concentrations of caffeine are then added** to the bath (with or without halothane) and isometric contracture tensions are recorded on a polygraph.
- Results: According to the caffeine concentration at which the contracture occurs.
- **Rigid MHS** muscles show contractures at **very low caffeine concentrations**.
- **Non-rigid MHS** muscles show contractures at **higher** caffeine concentrations.
- **Normal** muscles show contractures at **very high** caffeine concentrations.
- 3. Other Tests:** only show abnormalities (but are not diagnostic).
- Electromyography (EMG) by repetitive stimulation.
- Motor unit counting.
- Microscopic examination of muscles.
- MRI scan of a stressed or ischemic muscle.
- Echocardiography.
- **Recently, micro-dialysis** is done to detect the increase in CO₂ after injection of caffeine directly into the muscle in vivo.

Anesthetic Management: (of susceptible MH patients).**Preoperative Management:****1. Preoperative patient assessment:** (by family history, C/P and investigations)

- If the patient is MH susceptible (i.e. +ve caffeine contracture test), elective surgeries should be in a high specialized centre and emergency surgeries, should be in a place with available contact with specialized centre.
- If caffeine contracture test is not available, the patient is considered susceptible to MH until proved otherwise.

2. Preoperative preparations: (for GA)

- Use a disposable fresh anesthetic **circuit**.
- Remove the vaporizers and open O₂ only at 3-5 L/min in the **anesthetic machine** or better use an anesthetic machine without a vaporizer.
- Change **CO₂ absorbent**.
- Prepare **cooling aids** e.g. cooling blanket, crushed ice and cold saline for i.v. infusions up to bypass pump team.
- Prepare **drugs** needed for treatment of acute crisis.
- **Avoid all drugs** supposed to be **triggering** to MHS.

3. Premedications:

- **Sedatives:** as benzodiazepines or barbiturates (**avoid phenothiazines**).
- **Anticholinergics are avoided.**
- **Prophylactic dantrolene** i.v. 2.5 mg/kg just before induction. Its value and use is controversial because;
 - There is no evidence that it decreases the occurrence of an acute crisis.
 - It has many side effects.

So, it is **not used routinely**.

Intraoperative Management:

Monitoring:

It should be meticulous especially for early signs of MHS.

- **ECG:** for tachycardia.
- **ETCO₂:** for progressive rising in CO₂ levels.
- **Pulse oximeter:** for hypoxia.
- **Temperature** by esophageal or nasopharyngeal probes.
 - + Needle probes inserted into the muscle.
- **Non-invasive ABP.**
- **Invasive arterial line** for ABP and AB gases.

Choice of Anesthesia:

a. Local and Regional Anesthesia:

- They are **safe** with both amide and ester LAs.

Some authors prefer ester LAs when a large volume is needed e.g. epidural blockade.

b. General Anesthesia:

Induction: 100% O₂ + Thiopentone + Fentanyl (to ensure enough depth of anesthesia).

Intubation: Topical anesthesia of the larynx with LA spray.

Any non-depolarizing muscle relaxant can be used (pancuronium raises the triggering threshold for MHS).

Maintenance:

O₂: N₂O + Opioid based anesthesia (fentanyl) + nondepolarizing muscle relaxant e.g. pancuronium, cis-atracurium.

Recovery:

Reversal of nondepolarizing muscle relaxants is debated, but it can be achieved safely with neostigmine and atropine (by some).

Postoperative Management:

- **Most cases of MHS occur in the immediate postoperative period**, usually not beyond 4 hours postoperatively. So, close observation for signs of MHS is mandatory.

Treatment of Acute MH Crisis:

Early Detection is the most important for successful treatment and can decrease the mortality rate from 60 % to < 20 % (it is 10% in the developed countries).

1. **Discontinue** all anesthetics and stop surgery.
2. **Call for help** (a phone call or an internet call to MH centers can help. The World Wide Web site is <http://www.mhaus.org>).
3. **Hyperventilation** with 100% O₂ (with high flow).
4. **Remove the vaporizers and soda lime** from the circuit and if possible **get another machine** with a new circuit and no soda lime canister or vaporizer, a non-rebreathing circuit is preferred.

PROBLEMS WITH ANESTHESIA

5. Insert a wide bore cannula for **CVP** and **arterial line** for invasive ABP and AB gases and **foley's catheter** and **nasogastric tube** + beside the **standard monitoring**.

6. **Dantrolene Na:**

- **Started early** (while muscle perfusion is still present).
- Initial dose: **2.5 mg/kg i.v** can be repeated if required **1-2 mg/kg every 5 min** up to a total dose of **10 mg/kg** depending on the patient's response.

7. **Aggressive cooling measures:**

If the body temperature is $> 40^{\circ}\text{C}$ or if the body temperature is rapidly increasing by;

- Decreasing the ambient room temperature.
- I.v. cold saline.
- Crushed ice for gastric, rectal or/and peritoneal lavage.
- Cooling blanket.
- Ice water packs over major vessels.
- Even pump bypass with heat exchanger.

Stop cooling measures when temperature falls below 38°C to avoid after drop.

8. **Correct acidosis:** by

- NaHCO_3 2 mEq/kg then it is given according to AB gases.

9. **Correct hyperkalemia:** by

- Correction of the acidosis may cause spontaneous correction of hyperkalemia.
- Glucose 25-50 gm i.v. 10 % with insulin 10-20 unit i.v.
- **No calcium is given.**

10. **Treat left ventricular arrhythmias:** by

- Procainamide 15 mg/kg (200 mg) i.v.

Avoid lidocaine because it is one of the triggering agents.

Avoid Ca^{++} channel blockers if **dantrolene** is given as they produce hyperkalemia.

11. **Ensure UOP:** by • Mannitol.

- Furosemide.

To avoid renal failure caused by myoglobinuria.

12. Give **energy substrates** e.g. glucose 25% or 50% with insulin.

13. Give **cardiopulmonary support** if needed.

14. Transfer the patient to the ICU for;

- Continuing close **monitoring**.
- Continuing the previous **treatment**.
- Continuing the **dantrolene**.

1-2.5 mg/kg i.v. repeated every 6 hours for 24 hours.

If the condition is stable convert to:

Oral dantrolene 2-4 mg/kg/day in divided doses for 2-4 days.

- Treating of the **complications**.

15. **Notify the patient and his family.**

- The patient should carry an identification band of all times.
- Screening tests for his family should be done.

N.B.; Differential Diagnosis of Masseter Spasm During Intubation: (3 M)

1. Myasthenia gravis.
2. Myotonia.
3. Malignant hyperthermia.

(VI) Adverse Drug Effects: (Drug Complications)

The risk of an adverse reaction increases in a non-linear fashion with the number of drugs given to the patient.

Types of Adverse Drug Reactions:

1. Hypersensitivity (Allergic Reactions):

It is not dose-related.

2. Idiosyncratic: Genetic (pharmaco-genetic disorders):

It is an inherited abnormal reaction to a drug due to a genetic abnormality.

- Malignant hyperthermia.
- Disorders of plasma cholinesterases.
- Porphyria.
- Glycogen storage diseases.
- Muco-polysaccharidosis (autosomal recessive).
- Osteogenesis imperfecta (autosomal dominant).
- Neurofibromatosis (Von Recklinghausen's disease)
- Marfan syndrome.
- Familial dys-autonomia.
- G6PD deficiency

3. Interaction:

- Pharmacoeutic.
- Pharmacokinetic.
- Pharmacodynamic.

See pharmacology

4. Others:

- Incorrect choice, dose or route.
- Other unwanted side effects (at therapeutic doses).
- Overdosage toxicity (at high doses).

Both are;

- Mostly unpredictable
- uncommon (20% of adverse drug reaction).
- Dose independent.
- They are not related to the drug's pharmacologic action.

Both are;

- Predictable, and preventable.
- Common (80% of adverse drug reactions)
- Dose dependent.
- Related to known pharmacologic action of the drug.

Hypersensitivity

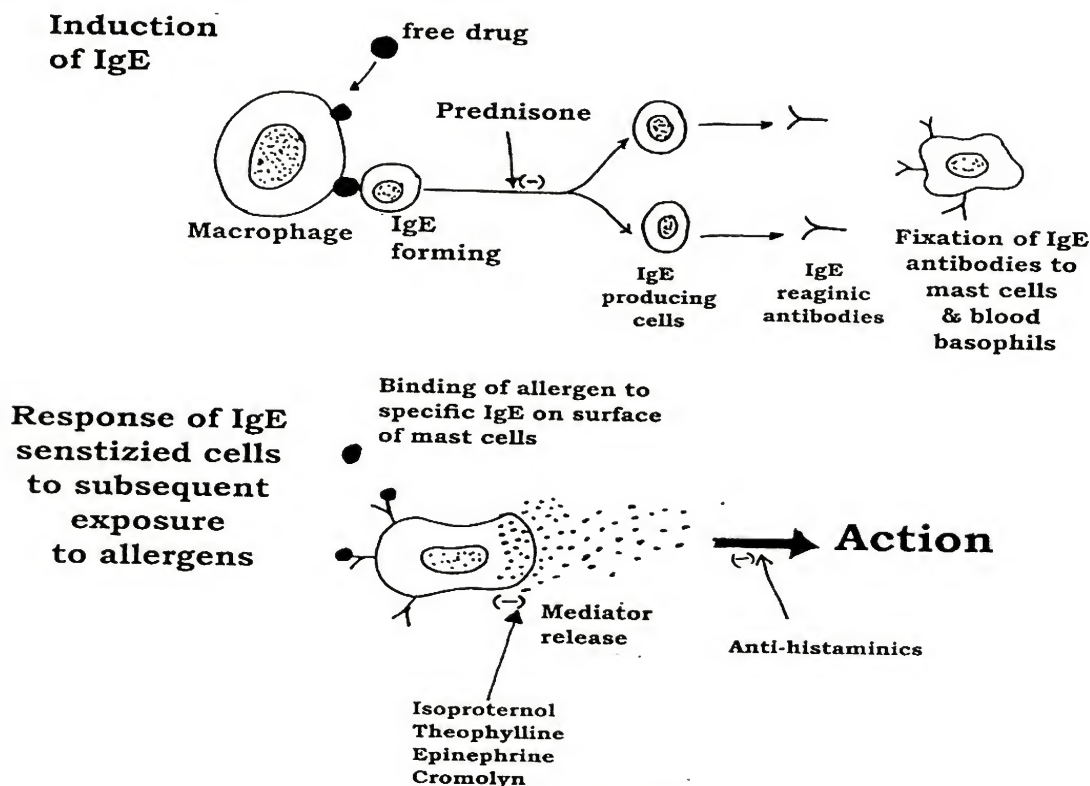


Figure 36-3; Type I reaction

PROBLEMS WITH ANESTHESIA**Types:****1- Type I Reaction (Immediate Type, Anaphylaxis):**

(Ana = Against, Prophylaxis = Protection)

- Initial exposure of a susceptible person to an antigen induces CD4 + T cells to produce IL-4, IL-5, IL-6, IL-10, and granulocyte- macrophages colony-stimulating factor (figure 36-3). These lymphocytes activate and transform specific B-lymphocytes into plasma cells which produce allergen-specific **Ig E** antibodies. The FC portion of these antibodies are fixed on the surface of tissue mast cells and circulating basophils.
- During subsequent **re-exposure** to the antigen, it binds to the Fab portion of adjacent Ig E antibodies on mast cell surface, inducing degranulation and release of inflammatory lipid mediators and other cytokines from the mast cells. The intracellular Ca^{++} increases leading to the release of mediators as histamine, kinins, leukotrienes (which was called slow reacting substance of anaphylaxis, SRS), prostaglandins, serotonin, platelet-activating factor. These mediators produce a **C/P (usually severe)**.
- It may occur without any previous exposure mostly due to immunological cross-reactivity e.g. penicillins, streptomycin, dextrans

N.B.; Anaphylactoid Reaction (Non-Immunologic Histamine Release):

- It is due to the **direct acting of drugs on cells** (mainly mast cells) to release leading to chemical mediators. It has no immunologic basis and does not depend on Ig E production. The C/P are as anaphylaxis (but usually benign as **VD, urticarial along the vein**) e.g. morphine, thiopentone, atracurium.....

2- Type II Reaction (Cytotoxic Reaction):

- It involves **Ig G or Ig M** antibodies. They bind to antigens on the surface of the mast cells and basophils leading to activation of the classic complement system or the alternative complement system. Both cause lysis of cells.
- E.g. - Methyl dopa produces autoimmune hemolytic reaction.
 - Quinidine produces thrombocytopenia.
 - Procainamide produces systemic lupus erythematosus.
 - Heparin-induced thrombocytopenia.
 - Hemolytic transfusion reaction.

3- Type III Reaction (Immune Complex):

- It occurs when **antigen-antibody (Ig G or Ig M) immune complexes** are deposited in tissues, activating complement and generating chemotactic factors which attract neutrophils to the area. The activated neutrophils cause tissue injury by releasing lysosomal enzymes and toxic products.
- E.g. - Serum sickness reaction.
 - Acute hypersensitivity pneumonitis.
 - Arthus reaction.

4- Type IV Reaction (Delayed Type, Cell Mediated):

- It is mediated by **CD4 + T lymphocytes** that have been sensitized to a specific antigen by a prior exposure. **Re-exposure** to the antigen causes these lymphocytes to produce **lymphokines** (interleukins, interferon, and tumor necrosis factor γ) that attract and activate inflammatory **mononuclear cells** over 48-72 hours.
- E.g. - **Allergic contact dermatitis** from topically applied drugs e.g. local anesthetics, anti-histaminics.....
 - Tuberculin-type hypersensitivity
 - Schistosomiasis.
 - Rheumatoid arthritis.

Type I Reaction (Immediate Type, Anaphylaxis):

It is the most severe type.

Mechanism:see above.

The chemical mediators released are; Leukotrienes, Histamine, PGs, Kinins, and Platelet activating factor. They cause an increase in capillary permeability, VD, bronchospasm, coronary spasm, and myocardial depression.

Predisposing Factors:

1. Age: It increases in **youth** (and decreases in pediatrics and geriatrics).
2. Sex: It is more in **females**.
3. **Pregnancy**.
4. **Known atopy**: Type I increases in atopic patients (e.g. extrinsic asthma, hay fever, or penicillin allergy). N.B.; Type IV increases in non-atopic patients.
5. **Previous exposure** to the drug.
6. Special solvents e.g. **Cremophor EL**.

C/P of Anaphylaxis: The onset can be delayed for 2-20 min, but it is usually immediate.

1. CVS: Hypotension, tachycardia and dysrhythmia up to cardiac arrest.
2. Pulmonary: Bronchospasm, cough, sneezing, dyspnea, laryngeal edema, and pulmonary edema.
3. Skin: Urticaria (hives), pruritis, facial edema and flushing, and s.c. edema as angioedema.
4. GIT: abdominal cramps, nausea, vomiting and diarrhea.

N.B.; Key signs during GA → hypotension, bronchospasm and urticaria.

Key signs during awake status → dyspnea, nausea and vomiting.

Investigation to detect susceptible patients:

1. Intra-dermal skin testing.
2. Leukocyte or basophil degranulation testing (Histamine release test).
3. Radio-allergo-sorbent test (RAST): It measures drug specific IgE in serum.

Prevention (Anesthesia in Susceptible Patients):

1. **Avoid re-exposure** to the antigen (if known) is the most important.
2. **Drugs:**

- Cromolyn Na.
- Nebulized bronchodilators.
- Corticosteroids.
- H₁ and H₂ blockers.

N.B.; Pretreatment with antihistaminics and/or corticosteroids produce no benefit.

3. **Give all drugs and solutions slowly and diluted** with close observation.
4. **Full resuscitation facilities** should be immediately available.

Emergency Management of Acute Major Anaphylaxis:

Early detection is very important.

a- Immediate Therapy:

1. **Discontinue** administration of the suspected drug.
2. **Call for help**.
3. **Discontinue surgery** (as there is an increased risk of coagulopathy) and **anesthesia** (as there is hemodynamic instability) if possible.
4. **A, B, and C protocol**
 - Maintain the airway with **100% O₂** + tracheal **intubation**.
 - **Mechanical ventilation** may be needed.
 - **Adrenaline** i.v 1 µg/Kg (0.5-1.0 mL 1:100 000 solution). It can be repeated if there is no response.

The usual dose is 5-8 µg/kg.

- **I.v. fluid expansion**, **colloids** 10 mL/kg are preferred because crystalloids can escape via the leaky capillaries.

PROBLEMS WITH ANESTHESIA

- Consider **external chest compression**.

b- Secondary Management:

1. Adrenaline-resistant bronchospasm:

- **Salbutamol:** initial dose; 250 µg i.v, maintenance; 5-20 µg/min. i.v.
- **Terbutaline:** initial dose; 250-500 µg i.v, maintenance; 1.5 µg/min. i.v.

Or • **Aminophylline:** 6 mg/kg i.v over 20 min.

2. **Hydrocortisone** 500- 1000 mg i.v or **methyl prednisone** 1-2 gm (its value is controversial).
3. **Antihistaminics:** **Chloro-pheniramine** 20 mg i.v slowly (especially if there is angio-neurotic edema).
4. **NaHCO₃** to correct acidosis; 0.5-1 mEq/Kg.
5. **Inotropes** as adrenaline or noradrenaline infusion.
6. **Anti-arrhythmics.**
7. Consider the possibility of **coagulopathy** so; a clotting screen should be done and AB gases for O₂ and acid base status.
8. Persistent hypotension: give **vasopressin**.

N.B.; Latex Allergy

Cause: Exposure to a latex antigen which is present in many surgical and anesthetic equipments e.g. gloves, tourniquets, endotracheal tubes, ventilator bellows, i.v. injection ports, ABP cuffs, face masks, urinary catheters, rectal enemas, inhalational of a latex antigen contained within aerosolized glove powder.

Mechanism:

- Type I hypersensitivity.
- Type IV hypersensitivity.

Risk Factors:

1. **Chronic exposure to latex** e.g. health care workers, patients undergoing frequent procedures with a latex item e.g. repeated UB catheterization, barium enema examination....
2. **History of atopy** e.g. patients allergic to banana, avocados, kiwis have antibodies that cross react with latex.
3. Patients specifically with **spina bifida, spinal cord injury or congenital abnormalities of the genitourinary tract.**

C/P:

- It ranges from mild contact dermatitis to life threatening anaphylaxis.
- It may be confused with reactions to other substances e.g. drugs, blood products because the onset of symptoms can be delayed for more than an hour after the initial exposure.

Investigations: The same as in anaphylaxis.

Preventions and Treatment: The same as in anaphylaxis.

Nowadays many manufacturers label their products "latex-free".

So; avoid latex exposure.

E.g. - Products containing latex (as above).

- Rubber stoppers should be removed from drug vials before their use and injections should be made through plastic stop cocks and use products which are latex-free e.g. Polyvinyl or neoprene gloves, silicone ETT, or laryngeal masks or plastic face masks.

N.B.; Protamine Allergy:

It can occur in;

1. Diabetic patients who receive protamine insulin.
2. Protamine reversal of heparin.
3. Protamine in blood product transfusion e.g. platelet.

Because there are cross reactions.

(VII) Complications of Patient Positions:

A- Physiologic Effects of Common Patient Positions:

- As • Trendelenburg position.
 • Reverse trendelenburg position.
 • Lithotomy position.
 • Prone position.
 • Lateral position.
 • Sitting position.
- } See before.

B- Perioperative Neuropathy:

Causes:

1. Stretch (traction)
 2. Compression
 3. Generalized ischemia
 4. Metabolic causes
 5. Direct surgical trauma to the nerve
e.g. severing of the long thoracic nerve during pneumonectomy.
- } Due to improper position
- } Ischemia to the nerve
- } Transient or permanent nerve structural or functional damage.

Risk Factors:

- 1- Old age.
- 2- High body mass index ≥ 38 .
- 3- Prolonged surgery.
- 4- Preexisting chronic nerve dysfunction.
- 5- Some anatomic variations e.g. shallow cubital tunnel.
- 6- Vascular disease.
- 7- Hypotension.
- 8- DM.
- 9- Prolonged postoperative bed rest.

A) Upper Limb Neuropathies:

1. Ulnar Neuropathy: (The most common nerve injury)

- External nerve compression by malposition as elbow flexion especially at $> 90-110^\circ$ (during prone position) or if the forearm is pronated because this can tighten the cubital tunnel retinaculum and directly compress the ulnar nerve (cubital tunnel external compression syndrome) (figure 36-4).

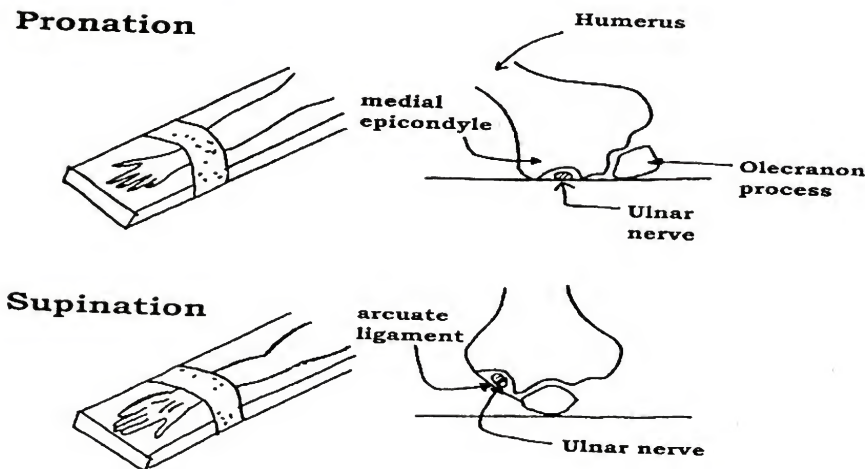


Figure 36-4: Ulnar nerve injury

PROBLEMS WITH ANESTHESIA**2. Brachial Plexus Neuropathy:** (The 2nd most common nerve injury).

- Stretch or compression of the brachial plexus **during sternal separation in median sternotomy** usually during internal mammary artery dissection where there is asymmetric retraction of the rib cage.

- Stretch of the brachial plexus **during the prone position** with:

B) Lower Limb Neuropathy: (Especially during the lithotomy position)**1. Common Peroneal Neuropathy:**

- Due to direct compression of the nerve during an **improper lithotomy position** by the leg holders.

2. Sciatic Neuropathy:

- Stretch of the nerve e.g. **simultaneous hyperflexion of the hip and extension of the knee as during the lithotomy position** especially if the patient is pushed caudally on the OR table while the legs are already fixed within the leg holders (for more exposure of the perineum). This action will increase hip flexion and leg extension that increases the injury.

(VIII) Nosocomial Infections:

- The incidence of patient-acquired infections from anesthetic practice is unknown and presumed to be low.
- Common recommendations;
 1. Equipment entering or contacting any sterile body area must be sterile.
 2. Equipment contacting mucous membranes, but not ordinarily penetrating body surfaces should be free from contamination, but need not be sterile.
 3. Equipment not ordinarily touching the patient or touching intact skin should be cleaned daily or whenever visibly contaminated.
 4. Equipment intended for a single-use should not be reused e.g. disposable syringes.
 5. Preservative-free medications should be prepared aseptically and the remaining drugs discarded immediately after use.
 - Uncontaminated (preservative-containing) multi-dose vials can be reused until the manufacturer's expiration date assuming the maintenance of aseptic technique during each use.
 6. Stopcocks and i.v. injection ports should be maintained with sterile techniques.
 7. Sterile techniques for **central venous lines** and the insertion site should be evaluated daily for infection. **They should be changed every 72 hours.**

(IX) Anesthetic Accidents

- Most perioperative patient's deaths are due to the patient's preoperative disease or the surgical procedure.
 - **The anesthetic mortality rates is < 1: 20 000**
- The most common cause of intraoperative cardiac arrest is **Hypoxia** from failing to ventilate a paralyzed patient.
- **As the routine preoperative evaluation of the patient is important, the routine preoperative checkout of equipment is also important.**
 - **As close observation of the patient intraoperatively is important, close observation of the equipment intraoperatively is also important.**

(X) Occupational Hazards in Anesthesiology

1. Chronic Exposure to Anesthetic Gases:

- **They can cause;**

1. A female anesthesia personnel who work in the operating room may be at a slightly increased risk of **spontaneous abortion** and of having offspring with **congenital abnormalities**.
2. A female anesthesia personnel may be at a slightly increased risk of **cancer**.
3. Both male and female anesthesia personnel may be at a higher risk of **hepatic disease** as serum hepatitis which is not totally explained.
4. A female OR personnel may be at an increased risk of **renal disease**.
5. Dentists and dental assistants may be at increased risks of **neurologic disease** from exposure to N₂O.

- None of these conclusions has been definitively proved and laboratory studies have failed to link trace concentrations of modern anesthetic agents to mutagenic, carcinogenic, or teratogenic consequences in animal models.

2. Infectious Diseases:

- **Viral DNA:** It is identified in the smoke plume generated during laser treatment.
- **Blood-Borne Infections:** e.g. Hepatitis B, C and HIV.

3. Substance Abuse:

- Anesthesiologists are at a high risk for drug addiction because of:
 - The stress of the anesthetic practice.
 - The easy availability of drugs with an addiction potential.
 - Curiosity aroused by the frequent example of a patient's euphoria after receiving opioids and sedatives.

4. Radiation Exposure:

- Anesthesiologists are at a high risk due to repeated exposure e.g. intraoperative imaging.

(XI) Complications of Regional Anesthesia

.....See later.

N.B.; Surgical Stress Response

It is 2 processes;

A) The Peripheral Response:

- It consists of the release of local inflammatory mediators at the incision site e.g. cytokines. These mediators sensitize the adrenal gland to hormonal stress messages.
- PGs inhibitors (NSAIDs) and/or LA infiltration variably block the peripheral response.

B) The Central Response:

- It consists of an afferent message via the spinal cord to the brain, where pain messages are integrated and responded to with efferent neural traffic back to the trauma site and the adrenals. The hypothalamic-pituitary adrenal axis is also activated. All inputs make the adrenals release CAs, cortisol, and other stress hormones leading to;
 - Increased HR and ABP.

- Hyper-coagulation.
- Increased metabolism.
- Decreased immune function.

PROBLEMS WITH ANESTHESIA**Effects of Anesthetic Agents:**

- **GA does not attenuate** the stress response, but may further impair the immune functions.
- **Opioids attenuate** the stress response **only at high doses**.
- **LAs attenuate** the stress response by blocking the non-nociceptive pathways.

Therefore, while all three anesthetics provide pain relief, only LAs (and to a lesser extent, high dose opioids) effectively attenuate perioperative stress. This is beneficial in cardiac, pulmonary patients and decreases postoperative ileus (as sympathetic stimulation decreases gut propulsive activity) and decreases postoperative hyper-coagulability.

Q: What are the postoperative complications related to anesthesia?

CHAPTER 37

REGIONAL & LOCAL

ANESTHESIA

Neuraxial Blocks

They include • Subarachnoid Anesthesia.

- Epidural Anesthesia.
- Caudal Anesthesia.

Surface Anatomy

- The **spinous processes** of the **cervical and lumbar spine** are nearly **horizontal** whereas those in the **thoracic spine** slant in a **caudal direction** and can overlap significantly. Therefore, when performing a lumbar or cervical epidural block (with maximum spinal flexion), the needle is directed nearly horizontal with a slight cephalad angle, and a significantly more cephalad angle on entering the thoracic epidural space.
- In the **cervical area**, the **first palpable spinous process** is that of **C2**, but the **most prominent** one is that of **C7 (Vertebra Prominens)**.
- With the arms at the side, the spinous process of **T7** is usually at the same level as the **inferior angles of the scapulae**.
- A line drawn between **both iliac crests** usually crosses either **the body of L4 or L4-5 inter-space**. Counting spinous processes up or down from these reference points identifies other spinal levels.
- A parallel line drawn connecting the **posterior superior iliac spines** crosses the **S2 posterior foraminae**.
- In slender persons, the sacrum is easily palpable, and the **sacral hiatus** is felt as a depression just above or between the gluteal clefts and above the coccyx.

Indications (of neuraxial blocks):

Analgesia and anesthesia by blocking **spinal nerves** and **dorsal ganglia**.

1. Preoperative: (Pre-emptive Analgesia) as blocking noxious stimuli from the periphery can decrease the phenomenon of spinal cord excitation, and this decreases pain and analgesia requirements.

2. Intraoperative:

- a- Surgeries **below the umbilicus** (including saddle block surgeries).
- b- Surgeries **above the umbilicus** which usually need addition of **light GA** to abolish the unpleasant sensation from visceral manipulations resulting from afferent impulses transmitted by the vagus nerve.

e.g.:

- **Obstetric:**See obstetric anesthesia for the advantages.
- **TURP surgery:**See genitourinary anesthesia for the advantages.
- **Orthopedic surgery:**See orthopedic anesthesia for the advantages.
- Pediatrics especially in **prematures** because it decreases the risk of apnea.
- Patients with **DM, thyrotoxicosis**.....see their advantages.
- Patients with **respiratory diseases** by low spinal anesthesia (it has no effect on ventilation, so it obviates the requirement of anesthetic drugs with depressant actions).

REGIONAL AND LOCAL ANESTHESIA

• **Congestive heart failure or ischemic heart disease** by low spinal anesthesia as a small decrease in the preload and afterload may be beneficial. Beside, it avoids the C.V.S. response to surgery (i.e. increased BP and HR) which are unwanted.

3. Postoperative: (Pain Control)

Advantages of pain control:

- It decreases C.V.S. complications as myocardial infarction.
- It decreases respiratory complications.
- It reverses the hyper-coagulable state induced by the response to surgery. This decreases DVT, and vascular graft obstruction.
- It allows return of bowel function rapidly and decreases postoperative ileus.
- It allows return of the mental state rapidly in elderly.
- It allows early hospital discharge.

Contraindications (of neuraxial blocks):**a. Absolute:**

1. Patient's refusal (lack of consent).
2. Coagulopathy and anticoagulant therapy.
3. Skin infection at the injection site or bacteremia.
4. Inadequate facilities or supervision.
5. Hypovolemia and shock.
6. Demyelinating CNS diseases.
7. Psychosis or dementia.
8. History of allergy to L.A.
9. Severe aortic or mitral stenosis.

b. Relative:

1. Spinal cord diseases or peripheral neuropathy.
2. Prior spine surgery or back pain.
3. Distant infection.
4. Mini-dose heparin, aspirin or other anti-platelet drugs.
5. Certain cardiac lesions.
 - Idiopathic hypertrophic subaortic stenosis.
 - Aortic or mitral stenosis.

As patients can not tolerate the V.D. due to the fixed C.O especially with high blocks.

6. Psychologic or emotional instability and uncooperable patients.
7. Prolonged surgery or surgery of an uncertain duration.
8. Surgical team resistance to an awake patient.
9. Respiratory failure (especially if a high block is to be done).
10. Increased ICT as a spinal block produces a leak that is harmful, and an epidural block increases CSF pressure that is harmful too.

Neuraxial Block with Anticoagulation**A- Absolute Contraindications:**

- **Full anticoagulation:** As • Thrombolytics or anti-thrombotic therapy.
 - Oral anticoagulant therapy.

B- Relative Contraindications: (The neuraxial blocks need special timing).

- **Temporary anticoagulation:** As • Intraoperative heparin.
- **Partial anticoagulation:** As • Low molecular weight heparin.
 - New anti-platelet agents.

C- No Contraindications:

- **Partial anticoagulation:** As • Low dose s.c. heparin.
 - Aspirin and other NSAIDs.

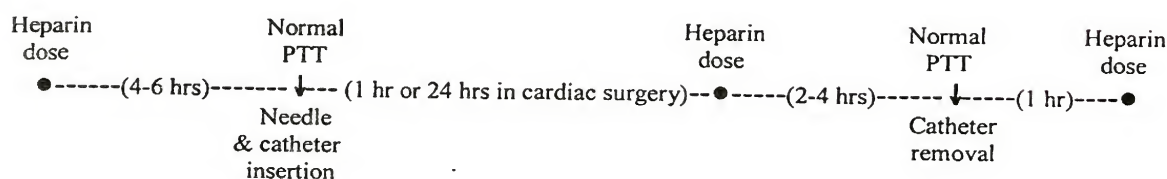
Anticoagulation includes:**Heparin:**

a- Low Dose (Un-fractionated) Heparin: E.g. subcutaneous heparin.

- There is **no contraindications or special timing**.

b- Large Dose (Un-fractionated) Heparin:

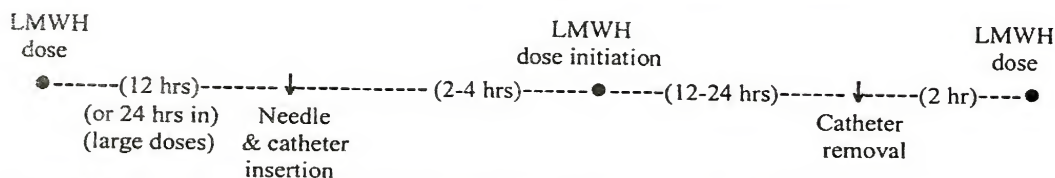
- E.g. for intraoperative temporary anticoagulation.
- There is a **relative contraindication needing special timing**.



- **Needle and catheter insertion:** at least 4-6 hours after stopping of heparin, with checking the PTT and one hour before the next heparin dose for most surgeries (and 24 hours for cardiac surgeries).
- **Catheter removal:** should be at least 2-4 hours after the last heparin dose with checking PTT and one hour before the next heparin dose.

c- Low Molecular Weight Heparin (LMWH):

- E.g. Enoxaparin as in DVT prophylaxis.
- There is a **relative contraindication needing special timing**.



- **Needle and catheter insertion:** at least 12 hours after LMWH (or 24 hours after large doses as 1 mg/kg twice daily enoxaparin) and 2-4 hours before initiation of LMWH therapy.
- **Catheter removal:** from 12 to 24 hours after the last LMWH dose and 2 hours before the next LMWH dose.

N.B.; Measurement of Xa activity is not useful in protection against hematoma.

New Anti-platelet Agents:

- There is a **relative contraindication**.
- They should be **stopped according to their half lives** before a neuraxial block is done.
- Half life of **Ticlopidine** is 14 days.
- Half life of **Clopidogrel** is 7 days.
- Half life of **Abciximab** is 2 days.
- Half life of **Eptifibatide or Tirofiban** is 8 hours.

- During this time, platelet function should return to normal. The minimum platelet count allowed is $> 150\,000/\mu\text{L}$ (for some authors, it is $100\,000/\mu\text{L}$).

Generally;

- A neuraxial block should be done only with **normal PT, PTT, INR, and platelet count** i.e. $> 150\,000/\mu\text{L}$ (for some authors, it is $100\,000/\mu\text{L}$).
- A **single spinal injection** is preferred than multiple epidural trials with a catheter.

Subarachnoid Anesthesia

(Intrathecal Block, Spinal Block)

It was started by August Bier in 1899

Patient Preparation

Informed Consent:

It must be taken

+ Preoperative visits with explanation of the risks and benefits of the procedure using lay terms with reassurance.

Physical Examination and Evaluation:

In addition to the usual physical examination, care is taken for;

- **Detection of contraindications** e.g. skin condition at site of puncture.
- **Lumbar interspace palpation.**

Laboratory Tests: for detection of contraindications: e.g.

- **Hb and hematocrit** as severe anemia will magnify the side effects of hypotension which may occur with a spinal block.
- **Coagulation profile** especially in susceptible cases as pre-eclampsia.

Premedication:

- **Sedatives** as benzodiazepines to **alleviate anxiety.**
as midazolam 1-3 mg i.m.

They must be administered at a proper time i.e. at the pharmacologic correct interval before the scheduled time of surgery.

Heavy sedation will obscure early signs of LA toxicity so it is better avoided.

- **Opioids** to **alleviate the discomfort of prolonged immobility.**

As - Morphine 0.1-0.15 mg/kg i.m.

- Meperidine 0.5-1 mg/kg i.m.

- **Preload the patient:** with 500-1000 mL crystalloid solution i.v. before or during the block to guard against hypotension (10-20 mL/kg).

Equipment and Safety

Patient Monitoring: ECG, NIBP, and pulse oximetry.

To allow early detection of C.V.S. collapse.

G.A.: must be available, if needed.

Resuscitation Equipment: (Regional anesthesia cart).

- An anesthetic breathing system with O₂ and a face mask or E.T.T.
- A laryngoscope with 2 sizes of blades and proper E.T.T. sizes.
- A table which can be tilted head-down rapidly.
- A suction apparatus.
- I.v. cannulas and fluids.
- Thiopentone to control convulsions and suxamethonium for intubation.
- Atropine and ephedrine to treat hypotension.

Techniques:

I.v. Access: I.v. infusion must be instituted before lumbar puncture is done.

Patient Position:

a. Sitting Position: It is the **easiest** position.

- The patient sits on the edge of the operating room bed with legs on a stool leaning forwards with arms crossed (with arching the back). The assistant stays in front of the patient to position and reassure him.

- This position tightens the skin and deep structures, and flexes the lumbar spine causing opening of the interspaces.
- It is the only position successful in **morbidly obese patients**.

b. Lateral Position:

- The patient is placed on the table, close to the anesthesiologist, most often with the surgical side of the body down (i.e. right side down for right leg surgery). The hips and knees are maximally flexed. The chest and neck are flexed towards the knees. The assistant stays in front of the patient to position and reassure him (figure 37-1).
- This facilitates flexion of the spine which is essential to open the lumbar inter-spaces.
- This position is useful for **obstetric patients** who become extremely agitated with each contraction.

c. Prone Position:

- The patient lies prone with his head slightly lower (i.e. Jack Knife position).
- This position is used for anorectal surgery using **hypobaric solutions**.
- It is difficult as CSF will not drip from the needle by gravity, but may be aspirated.

Identification of Anatomic Land Marks:

- After positioning of the patient, **iliac crests** are palpated and thumbs are extended to meet in the midline, they will press down in the interspace **L4 and L5**. This is called **Tuffier's line**.

- The best interspace is identified and marked with a finger nail imprint or skin marker.

Asepsis: by no touch technique.

Infiltration of L.A.

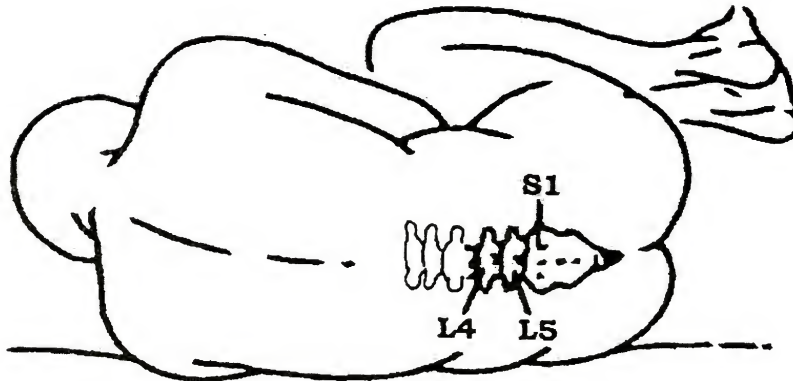


Figure 37-1; Lateral position

Needle Technique

The **spinal needle bevel** should be inserted while facing **laterally** to separate (not cut) the longitudinal fibers of the dura to decrease post-spinal headache.

a) Midline Technique:

- Due to the downward angle of the spinous process in the lumbar region, the skin wheal is raised just below the upper spinous process.
- The needle is directed so as to pass just under and parallel to this spinous process in the midline, taking into account the slightly cephalad location of the inter-laminar space. Smooth passage suggests that the approach has been correct.
- Contact with bone, if superficial, it is a spinous process.
if deep, it is a lamina (in the midline) or a pedicle (off the midline).

This information can be used to redirect the needle (Figure 37-2).

- When the needle leaves the s.c. tissues and enters the supra-spinous and inter-spinous ligaments, an increase in resistance is felt. Another **increase in resistance is felt as the ligamentum flavum is penetrated**. When the dura is punctured, a decrease in resistance is felt.
- A successful dural puncture is confirmed by withdrawing the stylet to verify free flow of CSF. **The needle is rotated 360 degrees** to verify free flow in each quadrant, and the syringe is then connected. CSF is

REGIONAL AND LOCAL ANESTHESIA

aspirated to verify that the needle is still communicating with the CSF after the syringe is connected, and has not moved further in or out.

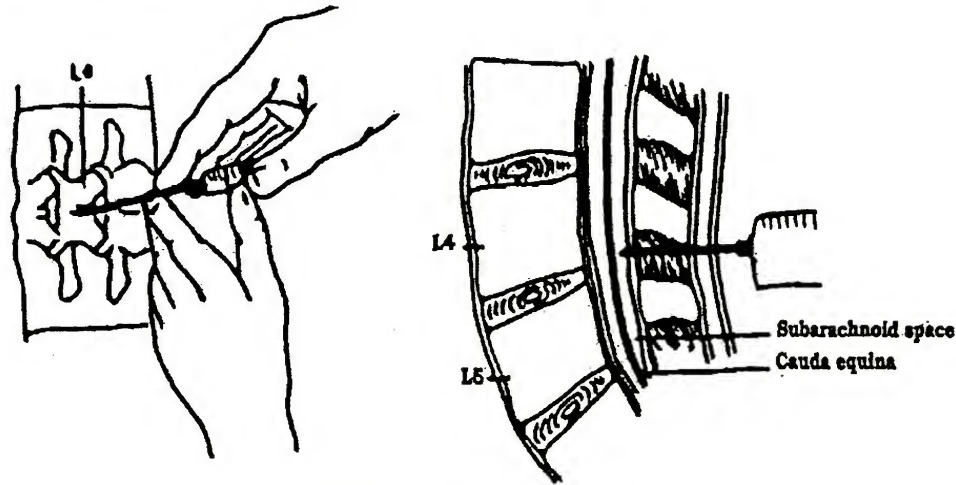


Figure 37-2; Subarachnoid block

- Then the medication is **injected slowly at a rate of 1 mL every 5 seconds**, the needle is withdrawn and the patient is placed supine.

N.B.; The spinal needle passes in the midline through the skin, s.c. tissues, supra-spinous ligament, inter-spinous ligament, ligamentum flavum, dura and arachnoid, while it passes para-median through the skin, s.c. tissues, ligamentum flavum, dura and arachnoid.

b) Para-Median Technique: (Lateral)

- This technique is selected when lumbar puncture is difficult, especially in patients with severe arthritis, kypho-scoliosis and prior lumbar spine surgery.

- The midline is identified and an interspace is chosen, then a skin wheal is raised **2 cm lateral** to the superior spinous process. The needle is **directed 10-15 degrees towards the midline** and then advanced.

- It may help to imagine that the needle reaches the midline 4-6 cm below the surface to select the angle of approach.

- With free flow of CSF, the procedure is then completed as the midline technique.

N.B.; The most common causes for difficulty are;

1. Poor patient position.
2. Failure to insert the needle in the midline.
3. Directing the needle laterally. This is seen easily from one side, so; it is apparent usually to onlookers, but not to the anesthetist.

New Techniques and Advances in Intrathecal Anesthesia.

1- Continuous Spinal Anesthesia:

By using a 25-gauge and a smaller Tuohy needle combined with tiny (32-gauge) micro-catheters (Avoid using epidural needles and catheters as they cause CNS injury).

2- Combined Spinal-Epidural Anesthesia:.....See later.

Factors Affecting Spinal Anesthesia

1. The Type of the L.A. Agent, its Dosage and Concentration:

- Lipid solubility increases the duration and potency.

And • Increasing the dose increases the duration, potency and distribution.

.....See before local anesthetics.

2. Vasoconstrictors:

- They increase the duration and the intensity of the block.

Drug	Preparation	Doses (mg) for 170 cm adult			Onset	Duration (min)	
		Perineum & lower limb	Lower abdomen	Up to T ₄		Plain	With epinephrine
Bupivacaine	0.5% plain 0.75% plain 0.75 in 8.0% dextrose	4-6	8-12	12-20	Slow	120-150	120-150 (no change)
Lidocaine	2% plain 5% in 7.5% glucose	25	50-75	75-100	Rapid	60	60-90
Ropivacaine	0.2-1% solution	8-12	12-16	16-18	Slow	90-120	90-120

N.B.; Effect of other additives:see local anesthetic drugs.

3. Specific Gravity (Baricity):

- It is the most important factor affecting the spread.
- Specific gravity of CSF = 1003 – 1008 at 37°C.

a- Hyperbaric Technique: (The most common)

- A hyperbaric solution has a **specific gravity heavier than that of CSF** so, it tends to move by gravity to a lower site.
- It is achieved by mixing the anesthetic agent with dextrose.
- E.g. **Bupivacaine 0.75% in 8.0% dextrose (specific gravity 1.0278)**
- The outcome is governed by the posture of the patient during and immediately after injection and until the agent is fully bound to the CNS structure.
- For saddle block (S₁) : The patient remains sitting for 3-5 minutes.
- For high thoracic (T₄₋₆) : The patient is turned to the supine position (head up) immediately after injection.
- Keeping the patient's neck flexed immediately after injection protects against progression into the cervical levels, by increasing the natural cervical curve which retards the cephalad movement of the hyperbaric L.A.

b- Hypobaric Technique:

- A hypobaric solution has a **specific gravity less than that of CSF** so, it moves away from the dependent area.
- The most common agent is tetracaine which is used for anorectal surgery with the patient in the prone position with the head slightly lower than the hips so, drugs move in a nondependent manner away from the head. This produces anesthesia from the level of injection and caudally up to the sacral dermatomes.

c- Isobaric Technique:

- An isobaric solution has a **specific gravity identical or very close to that of CSF** so; it stays at about the same level of injection.
- The most common agent is **bupivacaine 0.5% plain (specific gravity 1.0058)**. It is slightly but insignificantly hypobaric at 37°C.

4. Posture:

During and after injection.....see before.

5. Intra-Abdominal Pressure: e.g. pregnancy, ascitis and valsalva maneuver.

This allows more proximal spread of an equivalent dose of L.A. within the subarachnoid space.

6. Spinal Curvature: e.g. scoliosis, kypho-scoliosis and prior surgery of the spine.

- **Difficult introduction** of the needle is encountered so a para-median approach is preferred.

REGIONAL AND LOCAL ANESTHESIA**7. Age:**

- The spinal and epidural spaces are thought to become smaller with advancing age. This produces a **more cephalad spread** of L.A.

8. Obesity:

- There is **difficulty** in palpating the spinous processes and locating the inter-laminar spaces.
- A **longer needle** than the typical 3-inch spinal needle is required.

9. Speed of Injection:

- Rapid injection increases **the height of the block**.

10. Barbotage:

- It increases **the height of the block** (no longer performed).

11. Patient's Height:

- An increased patient's height requires a higher dose to reach the same level as compared with a shorter patient.

12. Needle Direction:

- Cephalad direction of the bevel increases the height of the block.

Complications

A) Acute:**1. Pain on Injection.****2. High (Total) Spinal Anesthesia:**

- **Due to:** Blocking the sympathetic system. This may occur;
- If spinal anesthesia spreads to the thoracic and cervical levels;
 - E.g. - During changing the patient's position up to 15-20 min injection.
 - Due to wrong intrathecal injection during epidural anesthesia.
- If only a high sensory block up to T4 occurs, this may cause block of sympathetic fibers 2-6 levels higher.

Sympathetic Blockade causes;

1- **VD of blood vessels** that causes hypotension and reduced VR that in turn decreases the CO and worsens **the hypotension**.

2- **Block of cardiac accelerator fibers** (T₁-T₄) causing **bradyarrhythmias**.

- C/P:

- Nausea, retching or vomiting may be the 1st symptoms of hypotension.
- Severe hypotension and bradycardia.
- Respiratory insufficiency up to apnea due to;
 - Ischemia of vital centers.

Or - Direct action of L.A. on the brain stem.

- Unconsciousness and dilated pupils.

- Treatment:**1) Circulatory Support:**

- Rapid administration of i.v. fluids.
- Head down tilt 5° after fixation of the local anesthesia level.
- Vasopressors:
 - Ephedrine (α and β agonist) 5 mg i.v. increments.
 - Phenylephrine (α agonist) is not preferred because it increases the heart O₂ consumption.
 - Anticholinergics: Atropine if the HR becomes < 60/min.
- 2) Respiratory Support: • 100% O₂.

- Assisted ventilation
- Control airway

if hypoventilation occurs.
if unconsciousness occurs.

- Intubation with I.P.P.V. if complete apnea occurs.

3. Over-Sedation:

- Sedation becomes excessive when the block is established. This increases the risk of respiratory obstruction or aspiration which may cause hypoxemia resulting in cardiac arrest.

4. Hypotension:

- It is more rapid than with an epidural block.

B) Postoperative:

1. Backache.

2. Post-Dural Puncture Headache (PDPH) (Cephalalgia):

Cause and Patho-physiology:

- Persistence of the dural puncture, with **leakage of C.S.F.** into the surrounding soft tissue, causes a **chronic decrease in CSF pressure.**
- The lowering of CSF pressure causes **downward traction** on the intra-cranial structures and on blood vessels which are attached to the dura, brainstem, and cranium. These structures are pain sensitive and cause acute vascular headache.
- Headache may occur due to **meningitis.**

Characters:

- It **begins** within **6-12 hours** up to **2-7 days** after lumbar puncture.
- It **persists** up to **6 weeks.**
- It **increases in the upright position** and **decreases in the supine position.**
- It is **throbbing** and it is associated with **nausea and vomiting.**
- It is **frontal or occipital.**

Predisposing Factors:

1. **Needle size:** Large sized needles produce more severe headache.
2. **Orientation of the bevel:** The fibers of the dura are arranged in a longitudinal manner, so the bevel, when laterally directed, enters the dura parallel to the fibers. Therefore, it separates rather than transects fibers, resulting in less severe headache.
3. **Age and sex of the patient:** Elderly and male patients have a less incidence of headache than **young and female** patients.
4. **Pregnancy:** It increases intra-abdominal pressure and consequently CSF pressure, that in turn increases CSF leak leading to headache.

Treatment:

a. Conservative: During the 1st 24 hours, to improve the ratio of CSF production to CSF leak and so improve the C/P.

- Aggressive hydration 6 L/day.
- Soft diet and stool softeners.
- Abdominal binders.
- Bed rest.
- **Simple analgesics** as; NSAIDs in mild cases.

Narcotics in severe cases.

- **Caffeine:** 300-500 mg i.v. or oral once or twice daily.

Recently: **500 mg caffeine and Na⁺ benzoate in 1 L of isotonic crystalloids** are given by i.v. infusion rapidly as caffeine is a potent vasoconstrictor and so; it prevents traction on the blood vessels and subsequent vascular spasm.

b. To close the dural puncture and prevent the downward traction:

Epidural blood patch:

- It is done, if the headache persists for > 48-72 hours after the puncture.

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- Inject **10-15 mL** (or till the patient experiences pressure in the ears) of the patient's blood (under complete asepsis), by the epidural needle, in the same site of lumbar puncture into the epidural space.
- It works at the raw surface of the dural tear serving as a site for deposition of platelets and formation of a subsequent hemostatic plug that closes the dural tear and prevents subsequent leakage of CSF.

3. Urinary Retention:

- Blockade of S₂₋₄ causes loss of tone in the urinary bladder and inhibits reflex voiding. Therefore, during this time, there is overfilling of the urinary bladder.

4. Meningitis:

- **Chemical (aseptic) meningitis:** due to caustic substances used to clean reusable spinal needles (obsolete) or to clean the back of the patient causing **transverse myelitis and anterior spinal cord syndrome**.
- **Infectious meningitis:** due to bacterial contamination after lumbar puncture especially if there is bacteremia. This causes an **epidural abscess** that needs immediate decompression surgery.

Signs of meningitis; nuchal rigidity, fever, and chills.

5. Vascular Injury: It causes an **epidural hematoma**.Cause:

Due to continuous bleeding from the epidural venous plexus. This occurs in patients with coagulopathy or taking anticoagulant therapy. So; a coagulation profile must be done.

Investigation:

- Contrast myelography.
- Contrast assisted C.T. scan.
- MRI.

Treatment:

Emergency decompression laminectomy.

6. Nerve Injury:**a- Permanent Nerve Injury and Paresthesia:**Cause and Risk Factors:

1. The needle **directly contacting** a section of the **cauda equina, the nerve roots** themselves, or **spinal cord below L₂** (a rare anomaly).
2. **Neural ischemia** due to vasoconstrictors, prolonged hypotension, or intra-neural injections that increase the intra-neural pressure > the capillary perfusion pressure or leads hematoma formation.
3. **Infection.**
4. **LA toxicity** so, prolonged exposure to high doses and/or high concentration especially of lidocaine, tetracaine (especially epinephrine), should be avoided.
6. **Pre-existing neurologic disorders.**

b- 6th Cranial Nerve Palsy:

- It occurs due to using large needles which decrease CSF pressure. This causes descent of the medulla and pons with subsequent stretching of the nerve causing photophobia and double vision.

c- Transient Radicular Irritation (TRI):

- It was previously called **Transient Neurologic Syndrome**.
- There is back pain which radiates to the buttocks or legs.
- The incidence increases with; lidocaine (16%) especially hyperbaric lidocaine 5% with adrenaline.

d- Cauda Equina Syndrome:

- It occurs especially with; • Repeated applications of LAs via an indwelling intrathecal catheter.

- Hyperbaric 5% lidocaine.

7. Other Complications:

1- Side effects of L.A. agents.

2- Vaso-vagal Attack:

3. Equipment Problems:

- Catheters (epidural or intrathecal) are liable to shear with attempted withdrawal of the catheter through the needle.
- Needles are liable to break most probably at the junction with the hub and so, they should never be inserted fully.
- Catheter coiling and subsequent knotting may occur, if it is inserted > 2-4 cm in the space.

Q: What are the neurologic complications after spinal and epidural anesthesia?

A: All complications should be discussed in details.

Epidural (Extradural, Peridural) Block

Indication:

The same as spinal anesthesia with the following advantages:

- It can be used for **long procedures**.
- It can be used for **high procedures** as in the thoracic and cervical regions.
- It can be used for **postoperative analgesia**.

Contraindications:

The same as spinal anesthesia.

Applied Physiology of the Epidural Space:

- The spinal cord is surrounded by three layers from inwards outwards;
- The pia matter which is adherent to the spinal cord.
- The arachnoid matter which is separated from the pia by the subarachnoid space (containing CSF) and separated from the dura by the subdural space.
- The dura matter which is the outer layer and separated from the bone by the epidural space.
- There is **-ve pressure in the epidural space** in about 30% of patients due to:
 1. Transfer of the -ve pressure in the thorax via the paravertebral spaces and by valveless veins between the epidural and the thoracic spaces.
 2. Indenting of the dura by the needle.
 3. Full flexion of the back.
- **Differential blockades:** see later.
- High concentrations of drugs produce dense sensory and motor blocks so; this is useful in orthopedic (hip) surgery.
- Low concentrations of drugs produce sensory blocks but minimal motor blocks, so this is useful in obstetric analgesia.

Equipment and Safety

- **Patient Monitoring:**As spinal anesthesia.
- **G.A:**As spinal anesthesia.
- **Resuscitation Equipment:**As spinal anesthesia.

Needles

The Standard Tuohy Needle: (figure 37-3)

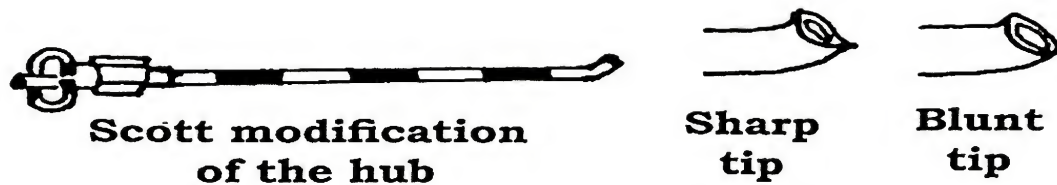


Figure 37-3; Tuohy needle

- It is typically 16-18 gauge, 3 inches long with a blunt bevel and gentle curve of 15-30 degrees at the tip (so as not to penetrate the dura). This curved tip is called the **Huber tip**. **Scott modification** of hub is the presence of an introducer (stilette) to facilitate threading of the catheter. It locks with the hub on the same side of the direction of the curve of the tip.

Crawford Needle:

It is a thin-walled needle with a straight blunt bevel without the curved Huber, allowing the catheter to pass directly via the end of the needle. So; it is used in cases where catheter advancement is difficult.

Weiss "Winged" Needle:

It has a Tuohy/Huber configuration with wings at the junction of the shaft and the hub allowing easier control over needle advancement with finger pressure (figure 37-4).

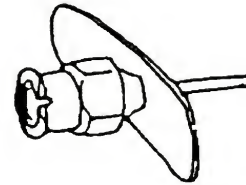


Figure 37-4; Weiss (winged) needle

Patient Preparation

- Informed consent.
 - Preoperative evaluation.
 - Premedication.
- } As spinal anesthesia

Technique

- I.v. access.
 - Patient position (sitting, lateral).
 - Identification of anatomic land marks:
- Epidural anesthesia can be done at any level of the spinal cord. The vertebral level is identified from the iliac crests.
- Asepsis
 - L.A. infiltration of skin.

} As spinal anesthesia

Needle Technique:

A. Identification of the Epidural Space:

After the needle pierces the ligamentum flavum, it enters the epidural space indenting the dura, creating a -ve pressure in the space, which is identified by:

1. Loss of Resistance:

- The commonest and easiest way.

- The needle is introduced via the skin to the inter-spinous ligament which is detected by firm resistance. At this point, the needle introducer (stilette) is removed and a syringe is connected that is filled with air or saline. Its plunger moves freely within the barrel.
- If the needle tip is within the inter-spinous ligament, attempted injection will create a firm feeling and an inability to inject.
- There are 2 ways to check the progress of the needle;
 - A 2-handed grip on the syringe and the needle with continuous firm pressure on the hub as the needle moves forward. When the needle enters the epidural space, the hub advances and the contents of the needle are injected (loss of resistance).
- Or • Advance the needle a few millimeters at a time, stopping and checking by touching the plunger and confirming that the needle tip is still within the ligament or has moved to where loss of resistance occurs (this way is quicker and more practical, but needs some experience).
- Inject saline or air, but large amounts of air may produce air bubbles which make incomplete or patchy blocks.

N.B.; Other methods to detect the epidural space is connecting the needle to a **sterile i.v. line** which is connected to an NS solution. When the needle enters the epidural space, a **free fluid flow will appear** from the i.v. line

2. Hanging Drop Technique:

- It needs more experience and may be reserved for a para-median approach to the **thoracic epidural space**.
- The needle (preferably a winged needle) is placed in the inter-spinous ligament. The hub is filled with saline and 1 drop is allowed to hang from the hub. As the needle is advanced via the ligamentous structure, the drop does not move.
- On penetration of the ligamentum flavum, with creation of -ve pressure in the epidural space, this drop of fluid is drawn into the needle indicating proper placement in the epidural space.
- With any tissue obstruction, loss of continuity in the fluid column within the needle will prevent the drop from being drawn into the hub of the needle, so that passage into the epidural space may not be recognized.

Other Methods:

1. Movement of a **bubble on Odem's indicator**: a glass tube with a fine bore containing saline and an air bubble which is attached to the hub of the needle.
2. **Macintosh's indicator**: a **small rubber balloon** attached to an adaptor which is attached to the needle and filled with air. When the needle reaches the epidural space, deflation of the balloon occurs.
3. **Macintosh-spring-headed needle**.
4. **U/S localization**.

B. Level Selected:

Initial experience should be gained in the lumbar region before progressing to sites above the termination of the spinal cord.

1- Lumbar Epidural Anesthesia:

a- Midline Approach:

- Identify the interspace easiest to locate, typically at L3-4 or L4-5.
- A skin wheal is raised in the midline.
- The needle is introduced as before.

b- Para-Median Approach:

- It is used in: - Prior spinal surgery.
Or - Advanced degenerative joint disease.
- It is a difficult technique.
- A skin wheal is raised 2-4 cm lateral to the lower aspect of superior spinal processes.

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- The needle is directed towards the midline in the same cephalad deflection used in the midline approach.
- The needle is advanced towards the midline in such a way that the space will be encountered 4-6 cm under the surface.
- After penetration of the skin, the syringe is connected to the needle.
- At first, some resistance is felt on piercing the para-spinous muscle, then a sudden increase in the resistance is felt on piercing the ligamentum flavum with a gritty coarse sensation. Lastly, loss of resistance occurs on reaching the epidural space.
- Some prefer the straight Crawford needle in the para-median approach to the lumbar epidural anesthesia.

2- Thoracic Epidural Anesthesia:

It is more difficult and more easy to injury the spinal cord so, during any attempt if intense, searing pain occurs, the epidural needle may be in direct contact with the spinal cord, so remove the needle and place it at a different level. It is done while the patient is in the lateral or sitting position.

a- Midline Approach:

- It is rarely done due to the short oblique (**steep cephalad direction**) configuration of the spinous processes.
- The patient is sitting and the needle is advanced usually for a shorter distance as the ligamentum flavum is 3-4 cm under the skin.

b- Para-Median Approach:

(Especially in the area of T4-T9 where maximum angulations of the spinous processes are seen)

- A skin wheal is raised **2 cm lateral** to the lowest aspect of the superior spinous process.
- The needle is directed towards the midline with a minimal angle of 10-15 degrees and advanced until the lamina or pedicle are contacted.
- The needle is pulled back and redirected in a slightly cephalad manner in an attempt to walk off the lamina, then the tip of needle should be in contact with the ligamentum flavum.
- The syringe is connected at this point, to identify the epidural space.
- As the epidural space is smaller than in the lumbar area, half the LAs volume is required as compared to lumbar doses.

3- Cervical Epidural Anesthesia:

- It is done most probably in the midline with the patient sitting, flexing his neck and with his head supported on the edge of the OR table.
- Typically, it is done at the interspace between C₅₋₆ or between C₆₋₇ (the most prominent is the spinal process of C₇).
- Injection of the LA drug is done while the patient is semi-setting.

Factors Affecting Epidural Anesthesia:

1- L.A. Agent and Dose:

• Agent:

Agent	Onset	Duration	
		without adrenaline	with adrenaline
Lidocaine	Intermediate	1 hour	2-2.5 hours.
Bupivacaine	Slow	4 hours	4 hours i.e. no change.
Ropivacaine	Slow	4 hours	4 hours i.e. no change.

- **Dose:** It can be increased by increasing the volume or the concentration.

a. Volume:

In general, a range of 1-2 mL of L.A. is given for each spinal segment to be anaesthetized e.g. if the epidural catheter or needle is placed at L₃₋₄ so, to block from T₆ to S₅ i.e. 16 segment = 16 x (1-2mL) = 16-32 mL are should be injected in the 1st dose, according to the patient's response.

b. Concentration: Increasing the concentration produces a greater motor block.

e.g.:	•	0.25- 0.125% Bupivacaine	}	Sensory block and minimal motor block.
		0.2 % Ropivacaine		
		1 % Lidocaine		
	•	0.75-0.5 % Bupivacaine	}	Dense sensory and motor block.
		0.75 % Ropivacaine		
		2% Lidocaine		

So,

A larger volume of low concentration produces a higher sensory level with less motor block. While a smaller volume of higher concentration produces a low density sensory level, but a more intense motor block.

- Assessment of the Success of the Epidural Block:

- **Sympathetic block** → by measuring **skin temperature**.
- **Sensory block** → by **pinpricking** or by using a nerve stimulator.
- **Motor block** → by **Bromage scale**
 - No block appears as a full ability to flex the knees and feet.
 - Partial block appears as an inability to flex the knees and resist gravity with full movement.
 - Almost complete block appears as an inability to flex the knees but, a retained ability to flex the feet.
 - Complete block appears as an inability to move the legs or feet.

- Incremental Doses (Top up Doses):

- They can be given via an epidural catheter according to the patient's response.
- Repeated doses should be injected before the block significantly regresses and the patient experiences pain.
- This is most easily evaluated by assessing the sensory level time to two segment regression i.e. the time from the injection, to the time when the maximum sensory level regresses two segments. When two-segment regression occurs, one should re-inject one-third to one-half the volume of the 1st dose.

2- Vasoconstrictors:

- Bupivacaine + epinephrine do not increase the time to two segment regression

Lidocaine or mepivacaine + epinephrine increases the duration.

3- pH Adjustment of L.A:

- LAs are stored commercially at a pH between 3.5-5.5 for chemical stability and bacteriostasis. At this pH, LAs are mostly in the ionic form.
- So, **increasing the pH** immediately before the injection **by a carbonating solution** or adding NaHCO_3 , increases the nonionic form which crosses the lipid nerve cell membrane, **accelerating the onset and increasing the density of the block.**

4- Posture:

- The patient's position affects spread of the epidural block, due to the effect of gravity or the effect of the position on the dimension of the epidural space.
- Subsequent studies show that this effect is probably due to the variability of the contour of the epidural space itself.
- The effect of the patient's position is obvious **in the cervical epidural block** as injection should be done while the patient is **in the semi-setting position**, otherwise a higher block occurs.

5- Age:

Doses are traditionally decreased with advancing age as spinal anesthesia.

REGIONAL AND LOCAL ANESTHESIA**6- Obesity:**

- There is a minimal relation between the cephalad spread of the epidural block and the patient's weight except in **morbid obesity**, as a **decreased dose** is necessary because the epidural space is smaller.

7- Height:

- There is a good relation between the cephalad spread of the epidural block and the patient's height.
- Short patients (5 feet i.e. 150 cm) should receive the lower range which is 1 mL/segment.
- Tall patients should receive the upper range which is 2 mL/segment.

So, **increased height of patients requires increased doses.**

N.B.; Generally;

- To increase cephalad spread, increase the volume.
 - To allow a more rapid onset (more rapid)
 - To increase the duration
- } Choose long acting agents, increase the concentration and add epinephrine

8- Pregnancy:

- There is a more cephalad spread so; decrease the volume used.

Complications**A) Acute:****1. Pain on Injection.****2. High (Total) Spinal Anesthesia:**see before spinal anesthesia.

- It is detected by **paralysis of the legs** so, after the test dose, the patient is asked to raise his/her whole leg and not only his/her toes (as toes' movement may not be abolished up to 20 min after spinal anesthesia).

3. Dural (Wet) Tap:

- It occurs due to **large needles** that produce immediate free flow of CSF, thus increasing the incidence of headache 40-80 %.
- To decrease the incidence of headache;
 - **Reposition** the epidural catheter at a different level after occurrence of the tap.
 - **Inject 0.9 % saline** as a bolus or continuous infusion 40 mL/hr extra-durally for 24-36 hours after surgery or labor.
 - **Simple analgesics.**
 - **Extradural blood patch:** 10-15 mL of the patient's own blood via the catheter immediately before its removal.

4. Intravenous Toxicity of L.A.**5. Hypotension:**

- It is **less rapid and less severe** than with spinal anesthesia.

6. Intravascular Catheter Insertion:

- It is detected by **epinephrine** as a test dose (15 µg), it will produce marked transient tachycardia.

B) Postoperative:**1. Headache:** after a dural tap.**2. Extradural Hematoma:**

- Using heparin or anticoagulants for patients intra- or postoperatively, must be done with a great caution.
- If the needle or the catheter during placement enters into an epidural vein, postpone heparinization for a reasonable period of time.

- If there is no vascular injury, heparinization can be done with rare incidences of extradural hematomas.
- Also care is taken during removal of the catheter while heparinization is indicated so, it is better to consult the surgical team to allow short stopping of heparin, then after removal of the catheter, institution of anticoagulants should take place after a reasonable period.
- **The most important is the alert observation and monitoring of the patient in the postoperative period.** Any sudden loss of recovered motor, sensory activity or sphincter tone, is usually due to the development of an epidural hematoma, which necessitates **decompression within 6 hours** to avoid a neurologic insult. If decompression is done after 12 hours, it will be totally ineffective.

3. Meningitis and Epidural Abscess:see before spinal anesthesia.

4. Neurologic Complications: as;

- Horner's syndrome.
- Trigeminal nerve palsy.
- Anterior spinal artery syndrome.

Q: Compare between spinal and epidural anesthesia?

Caudal Anesthesia

The caudal space is the sacral component of the epidural space.

Indications: Anesthesia or postoperative analgesia for;

1. Adults: Procedures involving the **perineum and sacral distribution**.
2. Pediatrics: Procedures involving the **sacral, lumbar, or even the thoracic regions**, combined with light G.A.

Contraindications:

- The same as spinal anesthesia.
- Morbid obesity is a relative contraindication due to difficulty in identifying the sacral hiatus.

Applied Anatomy of the Caudal Space:

- The sacral hiatus is covered by the sacro-coccygeal ligament.
- The sacral hiatus is absent in 5-10% of people so, entry into the caudal epidural canal is impossible.
- The dural sac usually ends at S₂ vertebra. It may extend lower.
- The ventral side of the sacral canal is the bone of the sacrum; a needle can enter into it. It contains bone marrow and so, represents a route of rapid injection of L.A. into the circulation with a potential for toxic reactions.

Applied Physiology of the Epidural Caudal Anesthesia:

- The same as epidural anesthesia.
- The level is directly related to the volume of the drug administered. So, it is possible to create a mid thoracic or even a high thoracic anesthetic level from the caudal region (especially in children) by injecting very large volumes of L.A.

Technique:

- **Equipment and safety:**As spinal anesthesia.
- **Needles:**
 - For adults: • 1.5 - 2 inch 20 - 22 gauge needle.
 - 22 - 24 gauge intravenous catheter for continuous anesthesia.

A Tuohy needle and catheter are difficult to be introduced due to their large sizes.

- For pediatrics: Smaller gauge needles are used (e.g. 25).

• **Patient Preparation:**As spinal anesthesia.

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- **I.v. Access.**

- **Patient Position:**

- **Prone:** on a surgical bed. The patient is flexed in such a way that the head and legs are lower than the hip joints.

- **Lateral:** as the fetal position with flexed shoulders and knees. It is suitable for pregnant females.

- **Identification of the Sacral Hiatus:**

- By using a finger of the non-dominant hand. It is felt as a concave opening.

- If this is difficult, placement of the finger in the midline midway between the tip of the coccyx and the level of the posterior superior iliac spine should yield some bony irregularity that suggests an opening.

- **L.A. Infiltration of the skin.**

Needle Technique:

- By using a **20-22 gauge 2 inch needle** which is inserted **perpendicular** to the skin until the ligament is encountered (noted as an increase in the resistance) (figure 37-5).

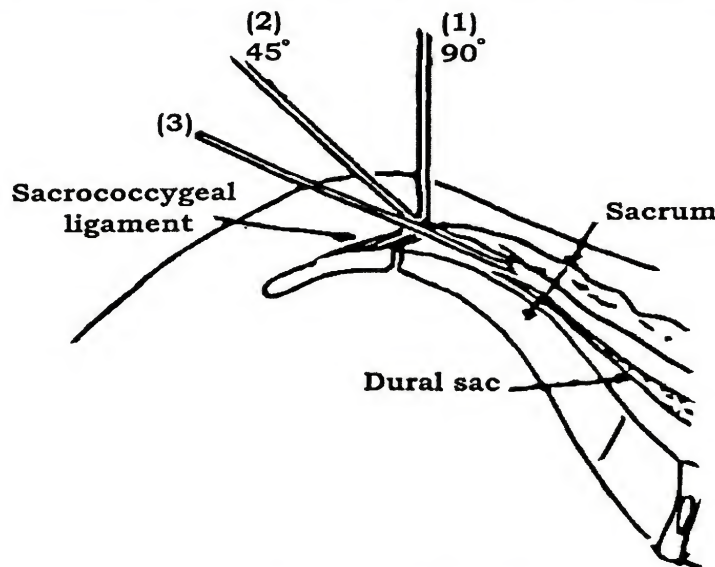


Figure 37-5; Caudal anesthesia

- At this point, the needle is lowered from 90 degrees to an angle of approximately **45 degrees to the surface** of the skin and advanced through the ligament.

- **When loss of resistance is perceived**, the needle is lowered **parallel to the skin** and advanced an additional 1-2 cm ensuring penetration into the caudal epidural space, but not to the distal end of the dural sleeve.

- Some **inject 2 -3 mL of air or saline**. If it is in the epidural space, the air's sound in the epidural space is heard by stethoscope. If it is not in the epidural space, skin elevation occurs which can be palpated. Also aspiration is done to avoid intravascular or intrathecal injection. **If CSF or blood are aspirated, do not perform the caudal block.**

- At this point, the solution is injected.

- **In adults:** - The volume of the solution is **1-2 mL/spinal segment** i.e. about **12-15 mL**

- The agent is 2% lidocaine or 0.5% bupivacaine.

- **In pediatrics**, the technique is easier because the sacral hiatus is easily identified and the sacro-coccygeal ligament is less calcified.

- For a sacral block: 0.5 mL/Kg of 0.25% plain bupivacaine.
- For a lumbar block: 1.0 mL/Kg of 0.2% plain bupivacaine.
- For a thoracic block: 1.1 mL/Kg of 0.1875% plain bupivacaine.

} Up to a
maximum
of 20 mL.

0.2% solution is prepared by mixing 4 parts of 0.25% bupivacaine + 1 part of normal saline.

0.1875% solution is prepared by mixing equal volumes of 0.125% and 0.25% bupivacaine.

- **Continuous anesthesia** can be done by a 22-24 gauge intravenous catheter after injection of the initial dose. Top up doses = 2/3 of the initial dose.

Complication:

The same as spinal and epidural block +

A misplaced needle:

- Injection in the subcutaneous tissue produces swelling
- Intravascular injection produces i.v. toxicity.
- Penetration of the dura produces a dural tap and intrathecal injection.
- In obstetrics, penetration of the rectum or the fetal head produces severe injury.

Peripheral Nerve Block

Choice of the Patient:

- The patient must be co-operable, without needle phobia, poorly controlled psychiatric diseases or a language barrier.
- Patient's anxiety level: mutilating surgery, diagnostic procedures for cancer and surgery on genitalia, make patients very anxious when they are awake in the operating room.
- The surgery position and duration must be tolerated by the patient, as an abnormal position can not be tolerated.

Patient Preparation:

- Informed consent.
- Patient evaluation: Care is taken to neurologic diseases and coagulopathies.
- Premedications.
- Equipment and Safety.
- Patient monitoring.
- G.A.
- Resuscitation equipment

} As spinal anesthesia

Immobile Needle: (By Winnie)

An extension set is inserted into the needle and the syringe is connected to the extension set. The needle can be stabilized against the body, once correct placement is obtained. Injection and aspiration tests can be performed with the other hand or by an assistant. This prevents needle movement during injection.

Techniques of Correct Needle Placement

1) Anatomic Location:

- Nerve sites depend on the precise anatomy e.g. intercostal blocks, digital blocks of hands and feet and ulnar and median nerve blocks at the wrist.

2) Field Block:

- Knowing the general location of a nerve allows deposition of a large amount of the agent in several places at that location.

3) Elicitation of Paresthesia:

- Placing a needle in direct contact with the nerve stimulates the sensory nerve leading to paresthesia in corresponding dermatomes. The needle's tip is either;
 - Near to the nerve (peri-neural). On injection, a slight increase in the intensity of parasthesia occurs, so continue injection.

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- In the substance of the nerve (intra-neural). On injection, intense searing pain occurs so, immediate stopping of injection is recommended.
- If you are in doubt, stop the injection.

4) Peri-Vascular Sheath Technique:

- Many nerve bundles are located close to vascular structures, often in a sheath. A blunt needle is used to feel a palpable click on piercing the sheath. Once the needle enters the sheath, if the needle is released, it will often pulsate.

E.g. - Classic axillary peri-vascular technique.

- Subclavian peri-vascular technique.

- Femoral approach to block the femoral, obturator and lateral femoral cutaneous nerves.

5) Trans-Arterial Placement:

- This technique includes transfixing the artery and injecting behind it e.g. brachial plexus block.

6) Nerve Stimulator (Nerve Locator):

Advantages: (over the parasthesia technique)

- 1- It has a **clear end point**.
- 2- It has a **high success rate** (>90%).
- 3- It has **minimal complications** (as the parasthesia technique may cause traumatic nerve injury).

N.B.; **Continuous Peripheral nerve Block**

Advantages: (over the epidural block)

- 1- Lower risk with low molecular weight heparin (the only complication recorded is retroperitoneal hematoma formation after a lumbar plexus block).
- 2- Less narcotic related side effects as urine retention.

Upper Limb Blocks

(I) Brachial Plexus Block:**Brachial Plexus Anatomy**

- It is formed from the anterior 1ry rami of C₅₋₈ and T₁.
- It supplies all motor and nearly all sensory nerves of the arm.

Parts of the brachial plexus:**A- The Supra-clavicular Part:****1- Roots:**

They are in the neck between the scaleneus anterior and medius muscle at the lateral border of the scaleneus anterior and above the 2nd part of the subclavian artery.

2- Trunks:

They are in the posterior triangle of the neck, and they are also related to the subclavian artery.

B- The Infra-clavicular Parts:**3- Divisions:**

They are behind the middle 1/3 of the clavicle.

4- Cords:

They are in the axilla behind the pectoralis minor muscle, and are related to the axillary artery (figure 37-6).

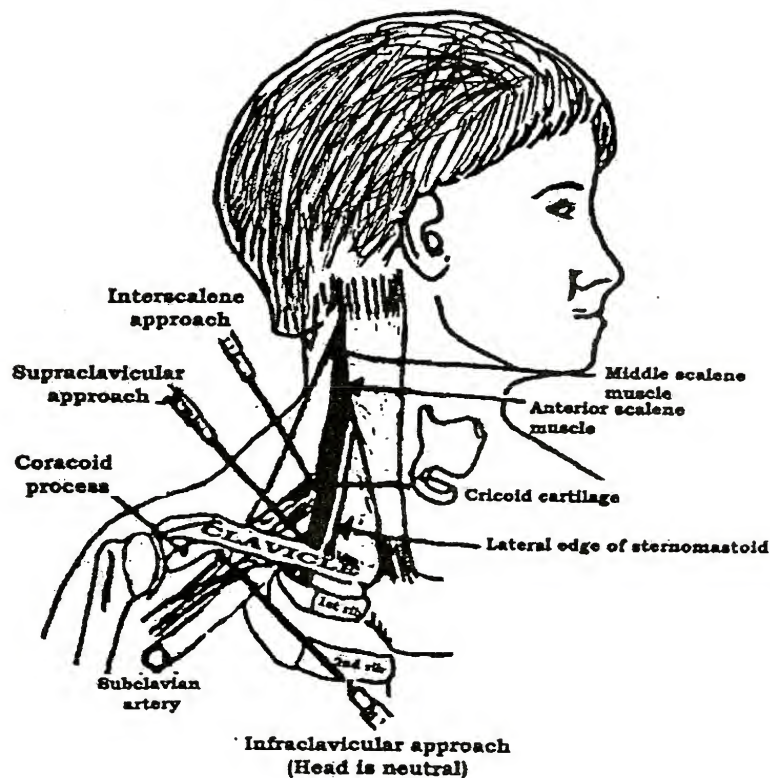


Figure 37-7; Technique of the brachial plexus

1. Interscalene Approach:

Indications:

- Procedures in the **proximal upper limb** e.g. shoulder reduction, upperarm or clavicular procedures.
- It is **less suitable for surgery of the hand** as blocking C₈-T₁ is difficult because it spares the ulnar nerve.

Aim:

To block the **roots of the brachial plexus** between the anterior and mid-scalene muscles.

Technique:

Patient's Position: The patient lies supine with the **head** rotated 30-45 degrees **towards the opposite side**.

Puncture Site: Palpate the interscalene groove:

- At the **level of the cricoid cartilage (level of C₆)** where the external jugular vein is located.
- The patient is asked to lift the head to this position. Identify the **lateral border of the sternocleidomastoid muscle**.
- With the neck relaxed, the hand is swept laterally. 1st feel the **groove between the sternocleidomastoid muscle and anterior scalene muscle**, then finally feel the **groove between the anterior scalene muscle and the middle scalene muscle (interscalene groove)**.
- With firm pressure, it is possible to feel the transverse process of C₆ and elicit paresthesia by deep palpation. A common error is to inject at the posterior border of the sternocleidomastoid and thus anterior to the interscalene groove (figure 37-7).

Insertion of the Needle: Through a skin wheal, a 25-gauge, 5/8 -inch B bevel needle is inserted (avoiding the external jugular vein). The needle is directed perpendicular to the skin with a **slight medial, caudal and dorsal** deviation, until either paresthesia or a motor evoked response of the arm is elicited. If paresthesia or a motor evoked response are too difficult to elicit, the needle entry site is too far posteriorly.

Dosage: After aspiration, inject **30-40 mL** of L.A. Recently a continuous interscalene technique has been developed.

Complications: (They all can be avoided, if one remembers that, it is a very superficial block)

1- **Artery:** Intra-arterial injection into the vertebral artery may cause **rapid grand mal seizure** (especially with the interscalene approach).

2- **Vein:** Intravenous injection causes **less rapid CNS excitation**.

3- **Space:** - **Pneumothorax** especially in COPD patients (mainly with the supra-clavicular approach). It may be delayed for several hours.

- Injection into **the epidural** (causing high epidural anesthesia), **subarachnoid** (causing total spinal anesthesia) or **subdural** spaces.

4- **Nerves:** In 30-50% of cases, due to their proximity.

Blocking of - **The stellate ganglion** → Horner's syndrome.

- **The recurrent laryngeal nerve** → Hoarseness of voice

- **The phrenic nerve** (in 100% of cases) → Hemi-diaphragmatic paralysis that in turn causes;

• Inability to cough.

• Unilateral increase in upper rib cage expansion.

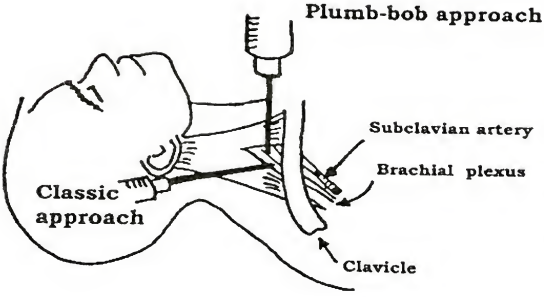
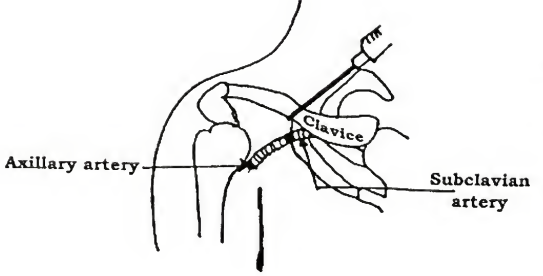
• Decreased FVC and FEV1 about 25%.

• Increased activity of intercostal and accessory muscles of respiration.

• Ipsilateral paradoxical inward motion of the hemi-abdomen during inspiration.

Therefore, careful patient selection is needed.

5- **Infection:** rare.

2- Supra-clavicular Approach	3- Infra-clavicular Approach
Indication: Procedures of the proximal and distal upper arm, forearm and hand i.e. the entire upper limb.	Indication: Procedures of the distal upper arm, forearm, and hand, but ulnar sparing is common.
Aim: To block the trunks of the brachial plexus when they cross the 1 st rib.	Aim: To block the trunks of the brachial plexus at the axillary sheath at a high level. N.B.; The musculo-cutaneous nerve is blocked.
	
Figure 37-8; supra-clavicular block	Figure 37-9; Infra-clavicular block

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<p>Technique: (Figure 37-8) Patient's Position: The patient lies supine with the head turned 30-45 degree to the opposite side. Puncture Site: At the mid point of the clavicle, palpate the subclavian artery by moving off the posterior border of the sternocleidomastoid just above the clavicle by one finger breadth. Insertion of the Needle: A 22-23 gauge, 1.5 inch B bevel needle is inserted via a skin wheal and directed caudally and slightly laterally towards the subclavian pulse, into the interscalene groove until paresthesia is felt or the 1st rib is encountered (walking the rib). If air is aspirated, a chest x-ray is mandatory. Dosage: After aspiration, inject 30-40 mL of L.A. Complications: The same as interscalene approach</p>	<p>Technique: (Figure 37-9) Patient's Position: The patient lies supine with the head placed neutral or turned to the opposite side. Puncture Site: At the mid point of clavicle on the inferior surface just lateral to subclavian artery pulse. Insertion of the Needle: 22-23 gauge, 3 inch spinal needle inserted via a skin wheal and directed laterally toward the humeral head (45°) until paresthesia is felt. The needle is directed away from the chest wall to avoid the pneumothorax. If air is aspirated so, chest x-ray is mandatory. Dosage: After aspiration, inject 30-40 mL of L.A. Complications: The same as the interscalene approach</p>
--	---

4- Classic Axillary Approach:**Indication:**

Procedures of the distal upper limb i.e. from the mid-humerus to the hand.

Aim:

To block the cords of the brachial plexus within the axillary sheath.

Technique:

Patient's Position: The patient lies supine with the humerus circumducted (not > 90 degrees) and the hands behind the head. Take care not to have the arms lower than the trunk as this causes forward displacement of the humerus, and interferes with axillary artery pulse detection.

Puncture Site: It is identified by one of the following;

a. Trans-arterial:

- Palpate the pulse of the axillary artery as proximal as possible, ideally proximal to the pectoralis ridge.
- The needle is inserted until bright red blood is aspirated. Then move the needle forward or withdraw it, just until blood aspiration stops. It is easier, if the immobile needle technique is used.
- After aspiration, inject either posterior or anterior or on both sides of the artery, while **distal digital pressure is applied** to ensure proximal spread in the sheath and blocking of the proximal branches as the musculo-cutaneous nerve.

b. Elicitation of Paresthesia:

- It is used if unplanned paresthesia is elicited during other techniques.
- The needle is inserted just;
 - Inferior to the pulse to block the ulnar nerve (it is medial and inferior to the axillary artery at the 3 to 6 quadrant of the clock face).
 - Superior to the pulse to block the median nerve (it is lateral to the axillary artery at the 12 to 3 quadrant).
 - Behind the pulse to block the radial nerve (it is dorsal to the axillary artery and close to it so, inject just deep to the artery, but not too deep, to avoid intramuscular injection of LAs) (figure 37-10).
- Pierce the sheath. Once paresthesia occurs, stop the needle.
- Burning, searing pain indicates intra-neural injection so, stop injection immediately to avoid nerve damage and reposition the needle.
- After aspiration, injection is done while **distal digital pressure** is applied.

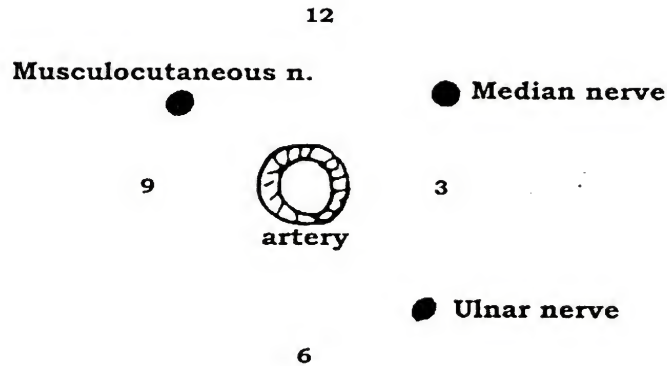


Figure 37-10; Relations around the axillary artery

c. Peri-vascular Injection:

- Insert the needle perpendicular to the skin and superior to the pulse to locate the sheath.
- Once the needle is inside the sheath and near the artery, disconnect the needle and **observe the transmitted pulsations**.
- The needle is then moved to a position almost parallel to the skin, and advanced 1-2 cm farther.
- After aspiration, inject while distal digital pressure is applied.

d- Nerve Stimulator:

- With a nerve stimulator, a motor evoked response is produced according to the nerve selected.
- Use lower currents for accurate location, as at 1 mA, it is highly specific and at <0.5 mA, it is a 100% success.
- After aspiration, inject while distal digital pressure is applied.

Insertion of the Needle:

A 25-gauge $\frac{3}{4}$ inch B-bevel needle is inserted via a skin wheal.

Dosage: After aspiration, inject 30-40 mL while distal digital pressure is applied.

N.B.; The musculo-cutaneous nerve, intercosto-brachial nerve and medial cutaneous nerve must be blocked to produce a complete block of the arm .

(II) Isolated Nerve Blocks:

1. Intercosto-Brachial and Medial (Brachial) Cutaneous Nerve Blocks:

Indication: In combination with brachial plexus block for;

1. Shoulder surgery.
2. Any upper limb surgery that involves the use of a pneumatic tourniquet.

Technique:

- **Patient's Position:** Circumduct the arm.
- **Puncture Site:** A linear fold injection from the deltoid prominence superiorly to the most inferior aspect of the medial upper arm (figure 37-11) either by;
 - Multiple injections with each subsequent needle insertion via a newly numb area.
 - Or - A single injection with a 3 inch spinal needle.

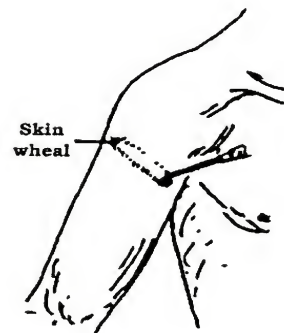


Figure 37-11; Intercosto-brachial nerve block

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- **Insertion of the Needle:** with a 1.5 inch, 22-23 gauge needle via a skin wheal.
- **Dosage:** inject 5 mL of L.A.

2. Musculo-Cutaneous Nerve

Block:

Indication:

In combination with brachial plexus block when distal block is needed.

Technique: 2 methods are present;

1. Placement of a 22-23 gauge, 1.5 inch needle into the substance of the coraco-brachialis muscle, and then do a field block by injecting 5 mL of L.A. into the belly of the muscle.

2. The belly of the biceps is palpated and displaced superiorly moving the artery away from the nerve.

A 23 gauge $\frac{3}{4}$ inch B bevel needle is inserted and directed downwards to the periosteum of the humerus then it is withdrawn a short distance (figure 37-12). This is performed several times with injection of 1-2 mL for a field block.

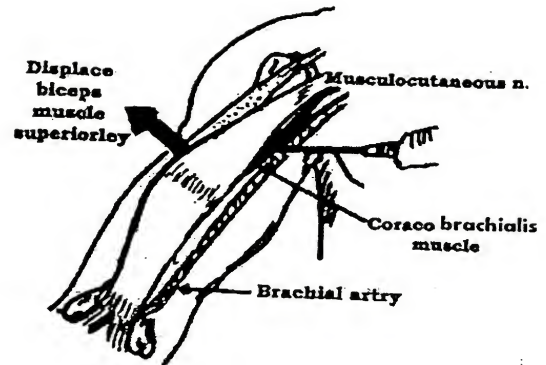


Figure 37-12; Musculo-cutaneous nerve block.

3. Radial Nerve Block	4. Median Nerve Block	5. Ulnar Nerve Block
<p>Technique: A- At the Elbow: Puncture Site: In the antecubital fossa, identify the lateral aspect of the biceps tendon at the flexion crease. Insertion of the Needle: A 23 gauge 1.5 inch B bevel needle is inserted via a skin wheal towards the lateral epicondyle until; - Paresthesia is felt. - A motor evoked response occurs (wrist extension). - The periosteum is encountered. Dosage: Inject 5 mL of L.A. in a fan-like fashion. B- At the Wrist: Puncture Site: The needle is placed between the radial artery (medially) and the flexor carpi radialis tendon (laterally). Insertion of the Needle: A Linear field block is done parallel to the wrist and deep to the muscle. Dosage: Inject 5 mL of L.A. in a fan like fashion.</p>	<p>Technique: A- At the Elbow: Puncture Site: In the antecubital fossa, identify the medial aspect of the biceps tendon at the flexion crease. Insertion of the needle: A 23 gauge 1.5 inch B bevel needle is inserted via a skin wheal between the brachial artery pulsations and the biceps tendon towards the medial epicondyle until; - Paresthesia is felt. - A motor evoked response occurs (wrist flexion). - The periosteum is encountered. Dosage: inject 5 mL of L.A. in a fan-like fashion. B- At the Wrist: Puncture Site: Identify the palmaris longus tendon by a resisted wrist flexion which is marked at the proximal flexion crease. Insertion of the Needle: Insert the needle deep to the muscle. Dosage: inject 5 mL of L.A. in a fan-like fashion.</p>	<p>Technique: A- At the Elbow: Puncture site: At the medial epicondyle, the nerve is palpated one finger breadth proximal to the arcuate ligament. Insertion of the Needle: A 23 gauge 1.5 inch B bevel needle is inserted via a skin wheal until paresthesia is felt or a motor evoked response occurs (finger movement). Dosage: inject 5 mL of L.A. in a fan like fashion. B- At the Wrist: Puncture site: The needle is placed between the ulnar artery (laterally) and flexor carpi ulnaris tendon (medially). Identify the flexor carpi ulnaris tendon by resistant flexion of the wrist. Insertion of the Needle: A Linear field block is done parallel to the wrist and deep to the muscle. Dosage: Inject 5 mL of L.A. in a fan-like fashion.</p>

These nerves are blocked to supplement and complete an inadequate brachial plexus block (figure 37-13, 14, 15, and 16).

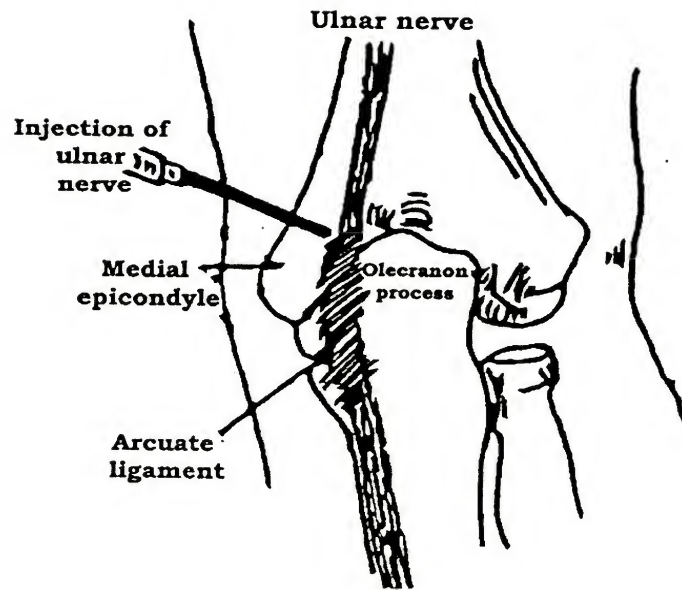


Figure 37-13; Block of ulnar nerves at the elbow

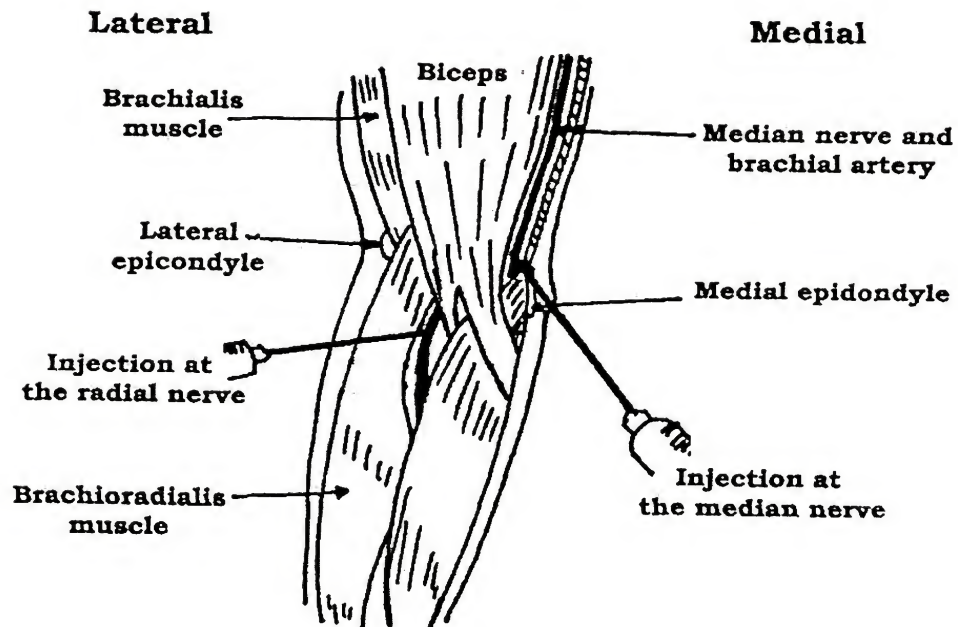


Figure 37-14; Block of radial and median nerves at the elbow

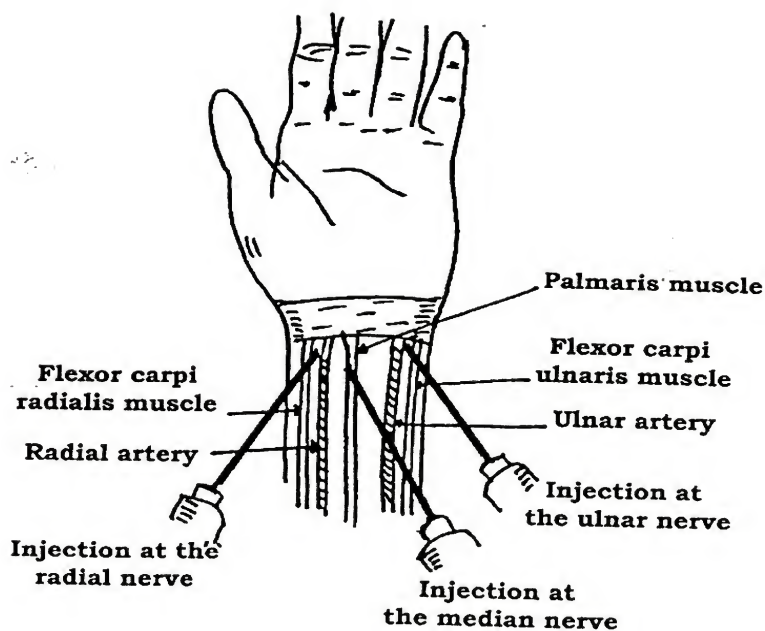


Figure 37-15; Block of the radial, median, and ulnar nerves at the wrist

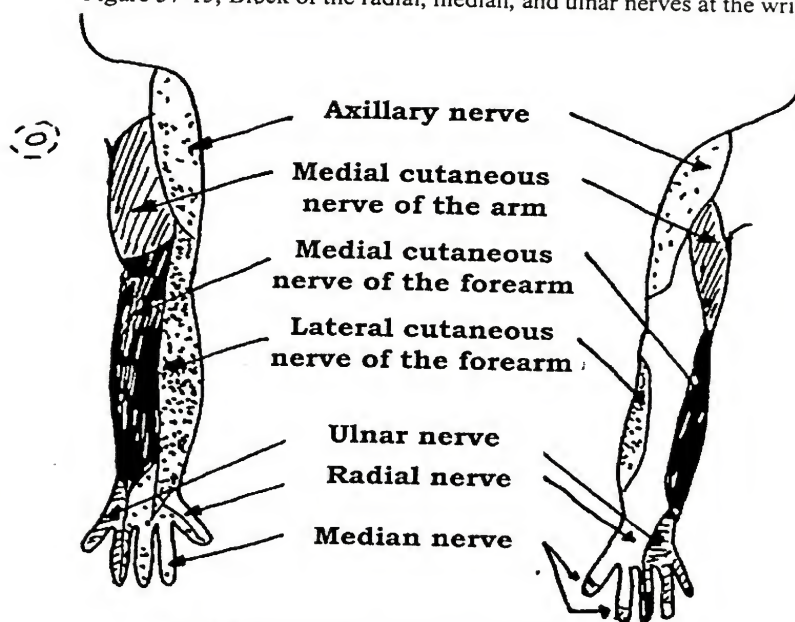


Figure 37-16; Nerve distribution of the upper limb

6. Digital Block:

Indications:

- Procedures at a single digit.
- As a supplement to an inadequate brachial plexus block at a digit.

Technique: At the Web Spaces:

- In the **digital web space**, a 25 gauge needle is placed at the base of the finger, and 2-3 mL of L.A. are injected near the periosteum while withdrawing.
- Enter from the **dorsal side** towards the **ventral side**.

- Avoid paresthesia as it causes hydrostatic compression of tissues. Avoid vasoconstrictors as they produce nerve injury (figure 37-17).
- It is done at the radial and ulnar sides of the digit, at the level of the digit.
- If anesthesia is needed for the nail bed give an additional injection of LA s.c., across the dorsum of the base of the proximal phalanx, to block the dorsal digital nerves and their branches.

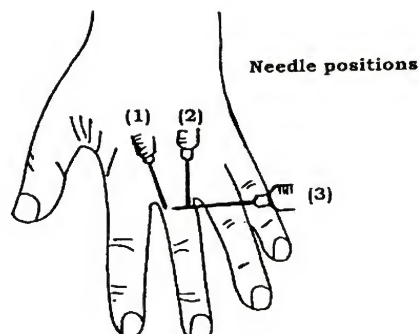


Figure 37-17; Digital block at the web space

Lower Limb Blocks

Clinical Application:

The area blocked	The nerve the blocked
1- To block the whole lower limb below the symphysis pubis.	Block the femoral nerve, obturator nerve, lateral cutaneous nerve of the thigh and the sciatic nerve.
2- To block the anterior aspect of the thigh (in fracture femur).	Block the femoral nerve alone.
3- To block the medial aspect of the thigh proximally.	Block the obturator nerve alone.
4- To block the lateral aspect of the thigh proximally.	Block the lateral cutaneous nerve of the thigh alone.
5- To block for procedures below the knees (legs and feet).	Block the femoral and sciatic nerves.
6- To block for procedures in the lower legs and feet.	Block the saphenous and sciatic nerves (the popliteal block).
7- To block a foot.	Ankle block.
8- To block a toe.	Digital block.

1. Femoral Nerve Block (L₂, 3, 4)

Indications:

- As a part of a whole lower limb block.
- For the anterior aspect of the thigh and fracture femur by blocking the femoral nerve alone.
- For procedures below the knee (leg and foot) by femoral nerve + sciatic nerve block.

Technique:

- Patient's Position: The patient lies supine.
- Puncture Site:

The femoral artery pulse is midpoint between the pubic tubercle and the anterior superior iliac spine, just 1 cm lateral to the artery and 1 cm below the inguinal ligament.

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- Insertion of the Needle:

A 23 gauge 1 inch B bevel needle is inserted via a skin wheal in a slightly **cephalad direction** where the sheath is felt. Either paresthesia or a motor evoked response (movement of quadriceps) at 2.5-6 cm depth occurs (figure 37-18).

- Dosage: After aspiration, 20 mL of L.A. is injected.

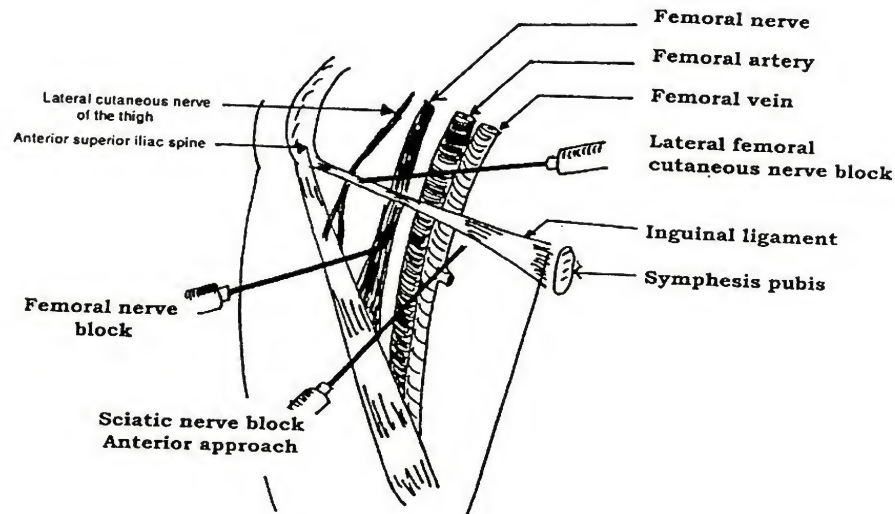


Figure 37-18; Block of the femoral, sciatic, and lateral femoral cutaneous nerve.

N.B.; The 3 in 1-Block of Winnie (The Inguinal Peri-vascular Block):

It is a block of the femoral, obturator and lateral femoral cutaneous nerves of the thigh

Indication:

- For a whole lower limb block in combination with a sciatic nerve block.

Technique:

The same as the femoral nerve block, but apply **distal pressure** and inject 30- 40 mL of L.A. This allows L.A. to ascend in the sheath to block these nerves proximally.

2. Lateral Femoral Cutaneous Nerve of the Thigh (L2, 3)

Indications:

- As a part of a whole lower limb block.
- For the **lateral aspect of the thigh** proximally.
- If a **pneumatic tourniquet** is applied to the thigh.

Technique:

- Patient's Position: The patient lies supine.

- Puncture Site:

2 cm medial and inferior to the anterior superior iliac spine over the inguinal ligament (figure 37-18).

- Insertion of the Needle:

A 22 gauge 1.5 inch needle is inserted via a skin wheal just **deep to the ligament** where a click is felt.

- Dosage:

After aspiration, 15-20 mL of L.A. is injected in fan-like manner.

3. Obturator Nerve Block (L_{2,3,4})

Indications:

- As a part of a whole lower limb block.
- For the medial aspect of the thigh proximally.
- If a pneumatic tourniquet is applied to the thigh.

Technique:

- Patient's Position: The patient lies supine.

- Puncture Site:

2 cm lateral and inferior to the symphysis pubis.

- Insertion of the Needle:

A 22 gauge 3 inch spinal needle is directed medially towards the inferior pubic ramus. A small amount of L.A. is injected to

decrease the patient's discomfort. Once the periosteum is struck, the needle is walked off the inferior ramus until it slips into the obturator foramen then it is advanced 3-4 cm acquiring a lateral and dorsal course (figure 37-19).

- Dosage:

After aspiration, 20 mL of L.A. is injected.

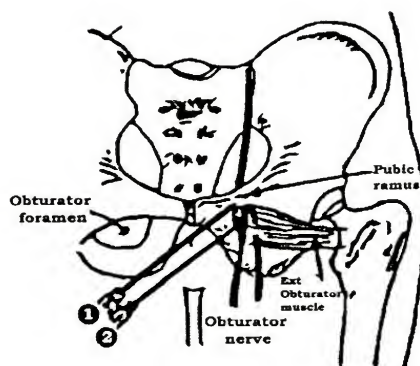


Figure 37-19; Obturator nerve block.

4. Sciatic Nerve Block (L_{4,5} - S_{1,2,3})

Indications:

- As a part of a whole lower limb block.
- For procedures below the knee (legs and feet) with a femoral nerve block.

Technique:

A- Anterior Approach:

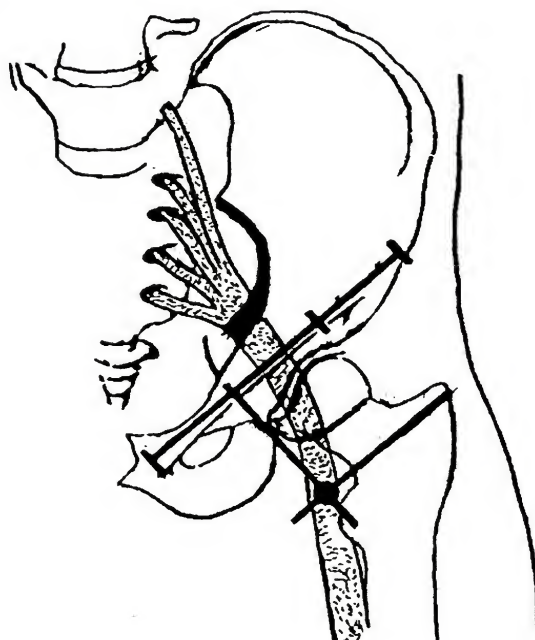


Figure 37-20; Anterior approach of the sciatic nerve.

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- Patient's Position: The patient lies supine.

- Puncture Site:

- **2 cm medial to the femoral artery pulsations** (figure 37-18)

Or • At the point of intersection of a line from the junction of the middle third and the medial third of the inguinal ligament, with a line parallel to the inguinal ligament at the greater trochanter level (figure 37-20).

- Insertion of the Needle:

A 22 gauge **3 inch spinal needle** is directed dorsally and laterally until the periosteum of the lesser trochanter of the femur is encountered at a **depth of 4-6 cm**. Then the needle is retracted to the subcutaneous area where its direction is corrected until the needle glides off the femur, then pushed forwards 2-4 cm further until paresthesia or a motor evoked response (foot dorsi-flexion or planter flexion) occurs.

- Dosage: After aspiration, **20 mL** of L.A. is injected.

B- Posterior Approach (of Labatt):

- Patient's Position: The patient lies in the **lateral decubitus position** on the sound side, and the **hip and knee are maximally flexed**.

- Puncture Site:

A line is drawn from the posterior superior iliac spine to the greater trochanter of the femur. Another line is drawn from the greater trochanter to the coccyx. The 1st line is bisected, and a perpendicular line is drawn from that point to the second line; the point at which it intersects the second line is the site of the needle insertion (figure 37-21).

These lines are called (**Labatt's lines**) which identify the sciatic nerve in the sciatic notch.

- Insertion of the needle:

A 22 gauge **3 inch spinal needle** is placed via a skin wheal perpendicular to the skin and at **4 – 6 cm from the surface** depending on the patient's weight and muscle mass, where paresthesia or a motor evoked response (dorsi-flexion or planter flexion of the foot) occurs.

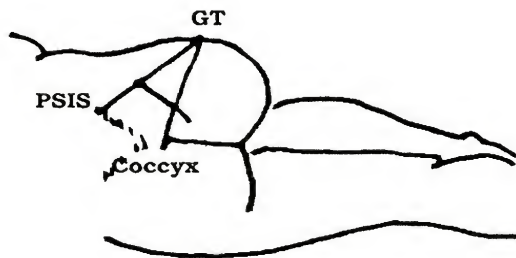


Figure 37-21; Posterior approach of the sciatic nerve

- Dosage:

After aspiration, **20 mL** of L.A. are injected.

Searing pain indicates an intra-neural injection and needs needle reposition.

C. Supine Approach (of Raj):

- Patient's Position: The patient lies **supine with both the hip and knee of the leg flexed to 90°**. This stretches the nerve and holds it firmly in the groove and makes the gluteus maximus thinner.

- Puncture Site:

Midway between the greater trochanter and the ischial tuberosity (figure 37-22).

- Insertion of the Needle:

A 22 gauge 3 inch short bevel spinal needle is placed at a right angle to the skin, better using a nerve stimulator.

- Dosage:

After aspiration, 20 mL of L.A. are injected.

5. Ankle Block (Mid-Tarsal Block, Foot Block)

Indication:

- For procedures of the foot.

Anatomy: There are 5 nerves to be blocked.

1- The saphenous nerve ($L_{3,4}$): It is a femoral branch that supplies the antero-medial aspect of the foot.

2- The superficial peroneal nerve ($S_{1,2}$): It is a sciatic branch that supplies the dorsum of foot.

3- The deep peroneal nerve ($S_{1,2}$): It is a sciatic branch that supplies the dorsal web space between the 1st and 2nd toes.

4- The tibial nerve ($S_{1,2}$): It is a sciatic branch that supplies the heel, the medial sole and part of the lateral sole of the foot.

5- The sural nerve ($L_5 - S_{1,2}$): It is a sciatic branch that supplies the lateral foot.

Technique:

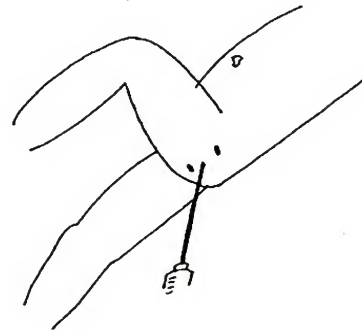


Figure 37-22; Supine approach of Raj

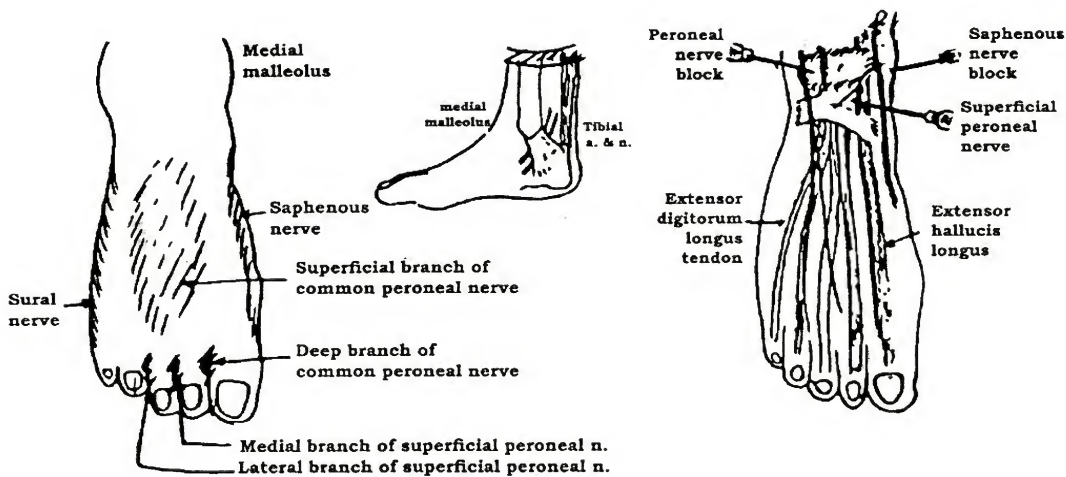


Figure 37-23; Ankle block

1- Saphenous and Superficial Peroneal Nerve Blocks:

They are blocked by s.c. infiltration on the dorsal foot.

- For the **saphenous nerve**: **above the medial malleolus** by one hand's breadth from the anterior tibial edge to the achilles tendon as a s.c. infiltration band.
- For the **superficial peroneal nerve**: just **lateral to the extensor hallucis longus**.

2- Deep Peroneal Nerve Block:

Via the numb area from saphenous infiltration, inject at the **inter-malleolar line** on both sides of the **dorsalis pedis artery**.

3- Tibial Nerve Block:

Posterior to the medial malleolus, inject on both sides of the posterior tibial artery.

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Above the lateral malleolus by one hand's breadth from the tibial edge to the achilles tendon as a s.c. infiltration band or **between the lateral malleolus and achilles tendon.**

- **Dosage:** After aspiration by a 22 gauge 1.5 inch needle, **5-10 mL** of L.A. are injected in each site in a fan-like manner. **Avoid vasoconstrictors** due to presence of end arteries.

6. Digital Block of the Foot

The same as the digital block of the hand.

7. Intra-articular Blockade

By 20 mL 2% lidocaine, for the anesthesia and analgesia of knee arthroscopy.

Truncal Blockade

1. Stellate Ganglion Block**Anatomy:**

- It is formed by the fusion of the **lowest 3 cervical ganglia and the 1st thoracic ganglia.**
- It lies in front of the head of the 1st rib and the 7th cervical and 1st thoracic transverse processes.

Indications:

1. **Diagnostic and prognostic value** in treatment of Raynaud's disease of the upper limb.
2. **Emergency treatment of;**
 - Accidental **intra-arterial injection** of thiopentone.
 - **Arterial injury.**
 - **Embolism** of the upper limb.
3. **Pain relief** in acute cases of herpes zoster ophthalmicus.
4. **To produce VD** in the vessels of the arm to facilitate A-V fistula surgery in patients with chronic renal failure.

Technique:

- **Patient's Position:** The patient lies supine with a fully extended head.

- **Puncture Site:**

2 fingers lateral to the supra-sternal notch of the sternum and 2 fingers above the clavicle. This point lies on the **medial border of the sternomastoid muscle** and over the transverse process of the **6th cervical vertebra** (figure 37-24).

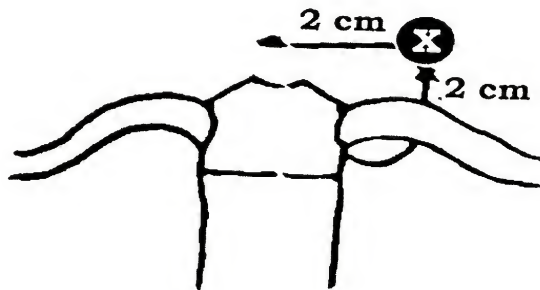


Figure 37-24; Stellate ganglion block

- **Insertion of the Needle:**

Retract the sternomastoid muscle and carotid sheath laterally by 2 fingers of the left hand. A fine **5-8 cm needle** is inserted via a skin wheal at a **right angle to the skin** until it comes in contact with the bone of the **6th cervical transverse process.**

Then withdraw the needle few millimeters. Its point will lie in a tissue plane anterior to the fascia covering the pre-vertebral muscles and in which, sympathetic fibers run.

- Dosage:

After aspiration, 10 mL of L.A. are injected.

Signs of a Successful Block:

1. **Increased temperature** of the skin of the upper limb (the only sure sign).
2. **Lacrimation.**
3. **Stiffness of the nostrils.**
4. **Horner's syndrome:** ptosis, miosis, enophthalmos, anhydrosis, and flushing of one side of the face (it is not a sure sign, as the sympathetic supply may be from a lower level as T₂).

Complications:

1. Space: - **Pleura:** Pneumothorax.
- **Extradural and subarachnoid blocks.**
2. Tube: - **Esophageal perforation** causing mediastinitis.
3. Vessels: - **Vertebral artery:** hemorrhage.
4. Nerves: - **The phrenic nerve:** respiratory paralysis.
- **The recurrent laryngeal nerve:** aphonia.
- **The brachial plexus.**

N.B.; Chronic stellate ganglion block:

- It is rarely used nowadays, (surgical sympathectomy is preferred).
- It is done by 1.5% lignocaine which is used as a test dose. Then 1-2 ml of 6% aqueous phenol is slowly injected.

2. Cervical Plexus Block (Sensory and motor of the neck)

Anatomy:

- It is formed of the **anterior primary rami of C₁₋₄**. It lies **opposite C₄ vertebra** under cover of the sternocleidomastoid muscle.
- Block either;
 - The superficial cervical plexus which emerges from the posterior border of sternomastoid muscle, supplying the skin of the neck and posterior occiput.
- Or - The deep cervical plexus which gives the phrenic nerve, muscular branches and communicating branches.

a. Superficial Cervical Plexus:

Indication:

For cutaneous analgesia of the neck and posterior occiput e.g. removal of a cyst.

Technique:

- Patient's Position: The patient lies **supine** with his shoulders slightly elevated and neck and head extended as for thyroidectomy, with the head turned away from the side to be injected.
- Puncture Site:

At the **junction between the upper and the middle 1/3 of the posterior border of the sternomastoid** where it is crossed by the external jugular vein.

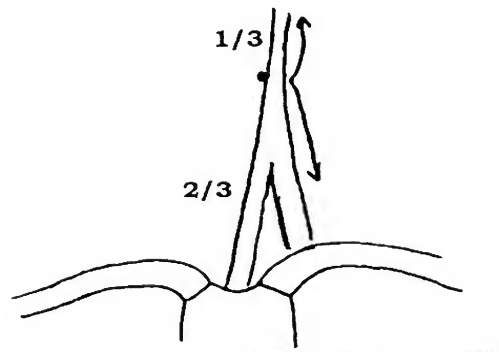


Figure 37-25; Superficial cervical plexus

REGIONAL AND LOCAL ANESTHESIA- Insertion of the Needle:

By using a 22 gauge 3 inch spinal needle via a skin wheel, which is introduced **between the skin and the muscle**. At first, the needle is **directed upwards** along the posterior border of the sternomastoid muscle. When the needle is withdrawn injection is performed. Then with the same skin puncture, **direct the needle downwards** along the posterior border of the sternomastoid muscle and inject as the needle is withdrawn.

- Dosage:

After aspiration, 20 mL of L.A. are injected.

b. Deep Cervical Block:Indication:

For thyroidectomy and carotid endarterectomy.

Technique:

- Patient's Position: The same position as, for superficial cervical block.

- Puncture Site:

Injection is done at **three points** at the transverse processes of C2, 3, and 4, which are one cm posterior to a line joining the mastoid process to **chassginac's tubercle** (the transverse process of the 6th cervical vertebrae at the level of cricoid cartilage). C2 transverse process is about 1-2 cm caudal to the mastoid process and C3 and C4 are about 1.5 and 3.0 cm caudal to C2 respectively. 3-5 mL of LAs are injected at each site (figure 37-26).

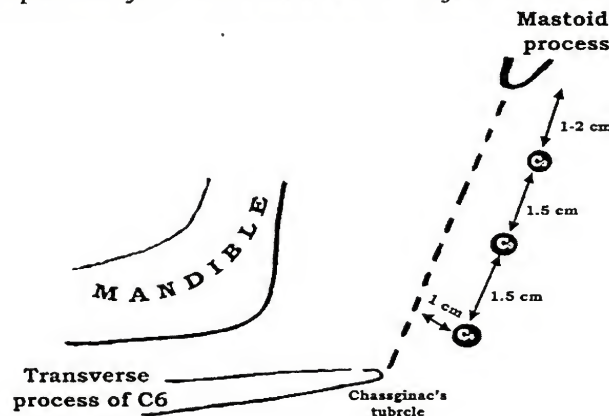


Figure 37-26; Deep cervical block

Complications:

1. **Space:** Accidental injection into the **cervical epidural or subarachnoid spaces**.
2. **Artery:** Accidental injection into the **vertebral artery**.
3. **Nerve:** - **Phrenic block**.
 - **Vagus and/or recurrent laryngeal nerve block** causing aphonia.
 - **Cervical sympathetic block** causing Horner syndrome.

3. Intercostal BlockIndication:

- Procedures in the **chest** e.g. rib fracture pain relieve, breast surgery.....
- Procedures in the **upper abdomen** with celiac plexus block.

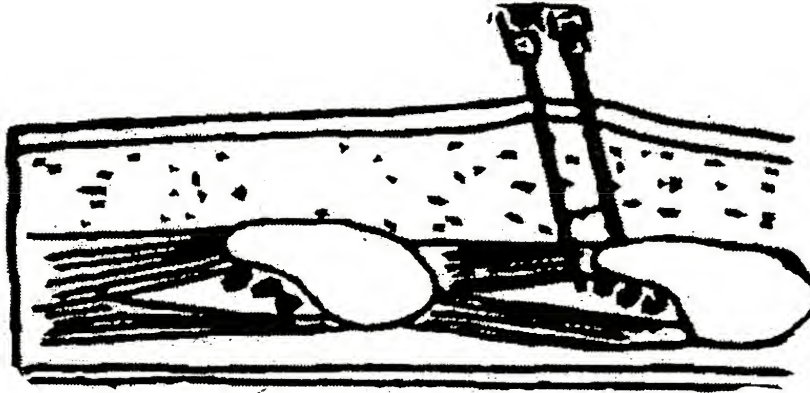
Technique:

Figure 37-27; Intercostal block.

- **Patient's Position:** The patient lies in the **lateral position**.

- **Puncture Site:**

Over the **caudal border of the correct rib at the mid-axillary line**.

- **Insertion of the Needle:**

A 22 gauge 3/4 inch needle is placed via a skin wheal. The needle strikes the rib and is walked until it steps off the rib inferiorly, then it is advanced 1 cm further where a distinct pop may be felt as the needle enters the neuro-vascular sheath (figure 37-27).

- **Dosage:**

After aspiration (to avoid vessel or lung injury), **3-5 mL of L.A.** is injected.

Complications:

• It causes the **highest blood level of L.A. per volume injected, of any block in the body**. So, take care to **avoid systemic toxicity**.

• Pneumothorax.

Q: Discuss intercostal nerve block?

A: Both the intercostal block and Paravertebral block are discussed.

4. Paravertebral Block

Indication: As the intercostal block.

It is **intercostal block** done near the midline for upper thoracic segments block due to interference of the scapula and shoulder with access to the intercostal nerve.

Technique:

- **Patient's Position:** The patient lies **prone**.

- **Puncture Site:**

Identify the spinous process

superior to the level to be blocked

which identifies the level of the transverse process.

The needle is injected **4 cm lateral** to this.

- **Insertion of the Needle:**

A 22 gauge 3 inch spinal needle with an **adjustable bead** is placed via a skin wheal. The needle is advanced until the transverse process is contacted. The movable bead is moved to the skin to mark the depth of the transverse process.

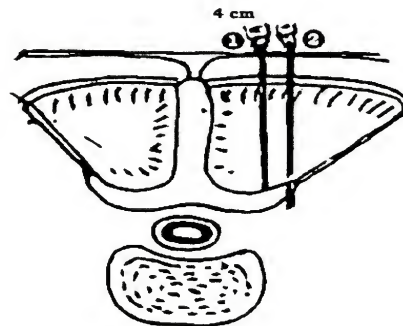


Figure 37-28; Paravertebral block.

REGIONAL AND LOCAL ANESTHESIA

The needle is withdrawn to the s.c. tissue and redirected to walk off the inferior edge of the transverse process and advanced to the bead. It is advanced further into the paravertebral space and within 2 cm from this point paresthesia should occur. Avoid advancing the needle further or repetitively moving in and out (seeking to elicit paresthesia) as this may cause pneumothorax (figure 37-28).

- Dosage:

After aspiration, 5-10 mL of L.A. are injected.

Complications:

- Pneumothorax.
- Subarachnoid block.

5. Celiac Plexus Block

Anatomy:

- They are 2 in number, lying on the aorta and crura of the diaphragm just above the pancreas at the level of the 1st lumbar vertebra, one on each side of the midline.
- Afferent fibers from the abdominal viscera (sympathetic and parasympathetic) pass via it.

Indications:

- Relief of the pain of **upper abdominal** malignancies, chronic pancreatitis or cholecystitis.
- Together with an **intercostal nerve block**, it could be used for upper abdominal operations.

Technique:

- Patient's Position: The patient lies **prone with a pillow under the abdomen**.

- Puncture Site:

Identify L₄ space then by counting upwards identify the 1st lumbar vertebra, **8 cm lateral to the midline** at the inferior edge of the 12th rib.

- Insertion of the Needle: **Under an X-ray screen.**

A 20 gauge 12- 15 cm spinal needle is inserted via a skin wheal. **Advance the needle medially creating an angle of 45 degree and upwards** for about 10-12 cm until it contacts the body of L₁. Then, the needle is partly withdrawn to be directed at a **slightly steeper angle until it just slips off the body of L₁**, then it is advanced **1 cm further**. The average distance between the skin and plexus is 7-10 cm (figure 37-29).

- Dosage:

After aspiration, **20-40 mL** of L.A. are injected. At first, a 1-2% lidocaine solution is used as a prognostic test. If it is useful and the patient benefits from the block, 50% alcohol is used that produces long standing pain relief. The other side is blocked similarly.

Complications:

1. **Spaces:** - Accidental **epidural or subarachnoid block**.
- Pleura: **pneumothorax**.
2. **Vessels:** - **Retroperitoneal hematoma** due to bleeding from the aorta, IVC, or abdominal viscera.
- Accidental **intravascular injection**.
- **Paraplegia** if 6% phenol is used, as it causes ischemia of the spinal cord.

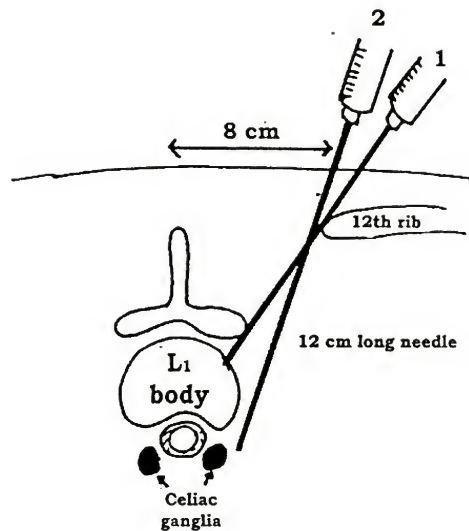


Figure 37-29; Celiac plexus block

- 3. Nerves:** - **Profound hypotension** due to extensive sympathetic block. It is treated by i.v. fluids, vasopressors (ephedrine) and wrapping the feet with elastic stocking.
 - **Failure of ejaculation** due to the pelvic sympathetic block.

6. Abdominal Field Block

Anatomy:

The abdomen is supplied by the anterior primary rami of T₆ up to L₁.

Technique:

In all surgeries performed under field block, it is necessary to **infiltrate the line of incision** both subcutaneously and intra-dermally, 15-20 min before surgery.

1- Wheals are raised in the following points:

Point (A): At the tip of the xiphisternum.

Point (B): One on each side at the 9th costal cartilage, where the rectus muscle crosses it.

Point (C): One on each side at the lateral margin of the rectus muscle just above the umbilicus.

Point (D): One on each side at the lateral margin of the rectus muscle, just below the umbilicus (figure 37-30).

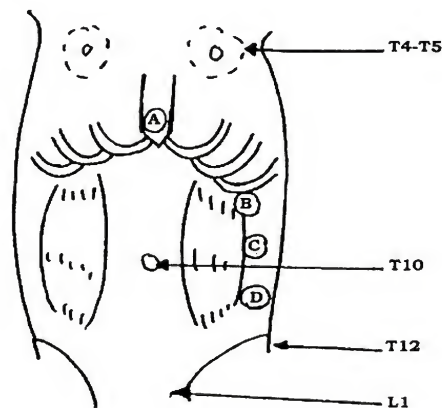


Figure 37-30; Abdominal field block.

2- Via wheals (B, C, and D), a needle is inserted perpendicular to the skin until it meets the resistance of the rectus sheath and pierces its anterior layer. It is advanced 0.5 cm and 5 mL of L.A are injected.

3- After withdrawal into the s.c. tissue, the needle is inclined upwards and downwards, so that more solution is deposited into the rectus sheath.

4- After completion of deep injections, wheals are joined together along the lateral margin of the rectus muscle by the lines of the s.c. injections, similarly, wheal (A) is joined to each wheal (B) along the coastal margin.

5- A total of **50-100 mL** of solution are used.

7. Inguinal Block

By blocking the ilio-inguinal and ilio-hypogastric nerves.

Indications:

- Inguinal surgery (as repair of an inguinal hernia).
- Genital surgery (as orchipexy).

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Technique: by one of the following methods (figure 37-31);

A) A 22 gauge 3 inch spinal needle is placed via a skin wheel at a point 3 cm medial and inferior to the upper aspect of the anterior superior iliac spine. The needle is placed perpendicular to the skin until it is just under the fascia. 15 mL of L.A. are injected in fan-like manner to block both nerves.

From the most lateral aspect of the incision, a 45 degree line towards the midline is imagined and the needle is inserted along this line for 4-6 cm. s.c. and 10 mL of L.A. are injected while withdrawing, cephalad and caudal to the incision.

B) Three wheals are made as follows:

Point (A): A finger breadth internal to the **anterior superior iliac spine (3 cm medial and inferior)**.

Point (B): Over the **spine of the pubis**.

Point (C): **1.5 cm above the midpoint of the inguinal ligament**.

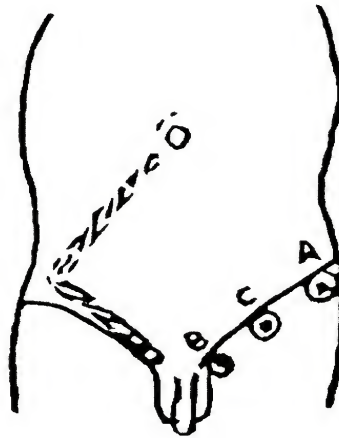


Figure 37-31; Inguinal block.

- Via wheal (A), insert a large needle vertically backwards till it is felt to pierce the fascia of the external oblique with a slight click. After aspiration, 15-30 mL of L.A. are injected in a fan-like shape to block both nerves.
- Via wheal (B), insert a large needle into the intra-dermal and s.c. tissues, in the direction of the umbilicus to block nerve twigs overlapping from the opposite side.
- Via wheal (C), a needle is inserted perpendicular to the skin until it pierces the aponeurosis of the external oblique. Inject 20 mL to block the genital branch of the genito-femoral nerve.
- Intra-dermal and s.c. injections at the line of incision are important.
- Infiltration is needed around the internal ring and hernial sac ring to avoid patient's discomfort.

8. Penile Block

Anatomy:

The **pudendal nerve and the pelvic plexus** supply the penis. There are 2 dorsal nerves that run along the sides of the dorsal artery. The **genito-femoral and ilio-inguinal** nerves give additional nerve supply to the base of the penis.

Indications:

For penile surgery e.g. circumcision (of choice), hypospadias repair and penile meatotomy with light GA.

Technique: With a 23 gauge $\frac{3}{4}$ inch needle, either by (figure 37-32);

a- **Ring Block:** A fan-shaped field (ring) block at the base of the shaft of the penis, 2-4 cm lateral to the base on both sides of the penis.

b- **Dorsal Nerve Block:** It is blocked by either;

- Penetration of Buck's fascia at the base of the penis bilaterally, at 10.30 and 1.30 O'clock.
- or • Injection one cm above the pubic symphysis, in the midline, at a depth of 3-4 cm.

Inject 3-5 mL to block the dorsal nerve.

N.B.; Avoid vasoconstrictors due to presence of end arteries i.e. there are no collaterals, so severe ischemia of the penis may occur.

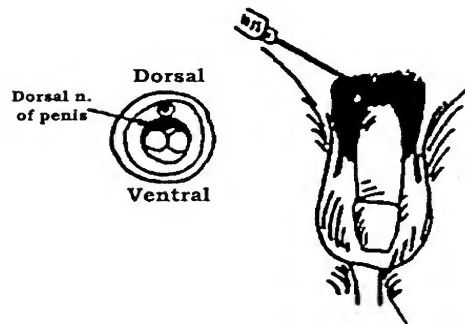


Figure 37-32; Penile block.

Intravenous Regional Anesthesia (Bier's Block)

Indications:

Short procedures in a limb.

Technique:

- An i.v. cannula is inserted into a vein as close as possible to the operative site. It is attached via extension tubes to the syringe containing the L.A.
- Avoid a proximal cannula as it decreases blocks and increases the liability to toxicity.
- Another i.v. cannula is inserted into the other hand.
- Drain the limb from blood by elevating it for 5 min and using Esmarch bandage.
- 2 narrow tourniquets are securely placed over the limb, or a special pneumatic tourniquet is used with a double bladder and 2 independent tanks.

The proximal (upper) tourniquet is inflated to a pressure of 100 mm Hg above the systolic BP.

- Inject 40-50 mL of 0.5% lidocaine or prilocaine for the upper limb.
- Or inject 60-75 mL of 0.5% lidocaine or prilocaine for the lower limb.
- After 5-10 min, the lower cuff is inflated 1st, then the upper one is deflated to decrease tourniquet discomfort.
- The onset is within 10 min and lasts 45-60 min.
- An additional refinement for improving the success of distal analgesia in Bier's blocks is to use a 3rd temporary tourniquet between the injection site and the other 2 tourniquets. This;
 - Prevents leaks under the pneumatic tourniquet.

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- Restricts the initial bolus of L.A. to the operative site.
- **At the end of the procedure, the cuff is deflated in stages** and the patient is carefully **observed for 10 min** after release of the cuff. Re-inflation may be considered if signs of toxicity arise. **Don't release the cuff until at least 20 min after injection** even if surgery is completed as this allows diffusion of the drug into the tissues.
- **Re-institution of the block** within 30 min of tourniquet release is possible **using 50% of the initial bolus**, as some of the drug is retained within the limb.
- **Bilateral blocks** may be performed **without exceeding the maximal recommended dose**. It is better if they are **done consecutively rather than concurrently**.

Contraindication:

- Raynaud's disease.
- Sick cell anemia.
- Scleroderma.

N.B.; Don't use bupivacaine as it causes toxicity.

Regional and Local Anesthesia in Pediatrics

It is usually regional or local anesthesia + light GA.

All Techniques: are as before with shorter needles.

The Dose: It should be adjusted according to the patient's body weight.

CHAPTER 38

INTENSIVE CARE

Intensive (Critical) care medicine or therapy deals with a potentially life-threatening illness.

Indication of Intensive Care Unit (ICU) Admission:

Critically Ill-Patients:

They are patients with **in life threatening conditions**, suffering from **multiple organ dysfunction** including cardiac or respiratory dysfunction, or patients who **cannot maintain their organ function adequately for survival and need active, aggressive and often invasive therapy** for;

- Appropriate management of a diagnosed condition.

Or - Resuscitation while a definitive diagnosis is made.

N.B.: ICU is not an appropriate place for patients whose death is inevitable due to their acute illness, and who need a high level of nursing care e.g. terminal cancer patients. It is better to nurse them in a separate place.

Brain Death

Definition: Irreversible cessation of all brain functions.

In some references, it is called “**Brainstem Death**”.

Value of Establishing the Brain Death Concept:

- 1- It relieves the **unjustifiable hope**, and prolonged anxiety of families.
- 2- It also relieves the **financial** burdens on families and society.
- 3- It allows **more efficient utilization** of medical resources.
- 4- It allows **potentially, harvesting of organs** for transplantation.

Brain Death Criteria:

Precautions on Assessing Patients for Brain Death Criteria:

- The **examination** should be performed;
 - At least **twice** (not less than 2 hours apart).
 - By **more than one physician** (one of them preferably a neurologist or neurosurgeon).
 - In the **absence of drugs** that - Block neuromuscular function.
 - Depress brain function.

So, a **toxicology screen** may be necessary if sufficient time (at least **3 days**) has not elapsed to exclude a drug effect.

- The patient should be **observed long enough** to establish, with reasonable certainty the irreversible nature of the injury.
- Brain death criteria can be applied even in the absence of;
 - Hypothermia (midbrain death is often followed by hypothermia).
 - Hypotension.
 - Metabolic or endocrine abnormalities.

Brain Death Criteria include:

a- Clinical Examination:

- 1- **Coma.**
- 2- **Absence of motor activity** including decerebrate and decorticate posturing, and motor activity in cranial nerve distribution in response to painful stimuli of the face (spinal cord reflexes may be preserved in some patients).
- 3- **Absent brainstem reflexes** including;
 - The **pupillary and corneal reflexes.**

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- **Vestibulo-ocular reflex (cold caloric test):** It entails irrigation of the external auditory canal with ice water. If the brainstem is intact, the eyes should deviate to the side of cold stimulation.
 - **Gag (and/or cough) reflexes** e.g. on passage of a catheter into the nose, mouth or bronchial tree.
 - **Oculo-cephalic reflex (Doll's eye test):** It is elicited by rotating the head horizontally to one side. If the brainstem is intact, the eyes deviate conjugately to the other side. This test should be performed only if the cervical spine is clear (not injured).
- 4- Absence of spontaneous respiration for 3 minutes** with the PaCO_2 rising at least to 50 or 60 mm Hg (mild hypoxemia may also be necessary in patients with chronic CO_2 retention). The apnea test should be reserved to the end, due to its detrimental effect on intracranial pressure).
- b- Confirmatory Tests:** (They are also done in some centers) include:
- 1- Isoelectric EEG.
 - 2- Absent brainstem auditory evoked potentials.
 - 3- Absent cerebral perfusion as documented by angiography, trans-cranial Doppler, or radio-isotopic scanning.

Medical Conditions Common in the ICU:**I - Respiratory Failure:** e.g.

- All causes of hypoxia and respiratory failure.
- All causes of pulmonary edema and ARDS.
- Near drowning.
- Smoke inhalation.

II- Cardiovascular Failure: e.g.

- All causes of shock.
- Acute myocardial infarction.

III- Renal Failure.**Q: Discuss ICU management of renal failure?**

A: The following are discussed; • Management of renal failure.

- Ventilation of the patient.
- Nutrition of the patient.
- Anti-stress ulcers and anti-DVT management.
- Monitor.

3 Main subjects will be discussed in details in this chapter:

- 1- Respiratory support.
- 2- Sepsis and septic shock.
- 3- Nutritional support.

Respiratory Support

It includes:

- 1- Ventilation: - O_2 Therapy.....see pharmacology.
- Mechanical ventilation (and positive airway pressure).
- 2- Other measures to preserve or improve pulmonary function.

Ventilation is Either;**A) Non-invasive Ventilation:** (i.e. without intubation)

E.g. • Nasal cannula or face mask.

- Negative pressure ventilators.....see later.
- Recently, Non-invasive mechanical ventilation (non-invasive positive pressure ventilation): It is either; - Non-invasive CPAP.

Or - Mask mechanical ventilation

It is used in the early course of respiratory failure, acute pulmonary edema, and in weaning.

Advantages of Non-invasive Ventilation:

- 1- Avoids intubation.
- 2- Preserves lower airway defense mechanisms, so it decreases nosocomial infection as pneumonia and sinusitis.
- 3- Decreases patient's discomfort.
- 4- Preserves speech and swallowing.
- 5- Decreases the amount of sedation, so there is no need for sedative drugs.
- 6- Allows application of therapy intermittently as the patient improves.
- 7- Advantages on non-invasive mechanical ventilation:
 - It is as effective as the standard mechanical ventilation in improving $\text{PaO}_2/\text{FiO}_2$ ratio.
 - It decreases the work of breathing so, it decreases hypocarbia and O_2 consumption.

Disadvantages of Non-invasive Ventilation:

- 1- Produces a limited access for airway management.
- 2- Produces discomfort and complications related to the mask.
- 3- Has a risk of inadequate ventilation due to leaks.
- 4- Needs an alert and cooperative patient.

B) Invasive Ventilation: (i.e. with intubation):

- E.g. • Mechanical ventilation.
- T-piece tube.

Mechanical Ventilation

Indications:1- Respiratory Gas Tension:a- Direct Indices:

- $\text{PaO}_2 < 50$ mm Hg in room air or $\text{PaO}_2 < 60$ mm Hg with $\text{FiO}_2 > 50\%$.
 - $\text{PaCO}_2 > 50$ mm Hg in absence of metabolic alkalosis i.e. pH is < 7.25 .
- (Discuss causes of hypoxia and hypercarbia).

b- Derived Indices:

- $\text{PaO}_2/\text{FiO}_2$ ratio < 200 mm Hg.
- $\text{P}_{\text{A-aO}_2}$ gradient > 300 mm Hg with FiO_2 1.0.
- $\text{Vd}/\text{Vt} > 0.6$
- $\text{Qs}/\text{Qt} > 20\%$

2- Clinical Indices:

- Respiratory rate > 35 breath / min.
- Respiratory muscle paradox.

3- Mechanical Indices:

- Tidal volume < 5 mL/Kg.
- Vital capacity < 10 -15 mL/Kg.
- Maximum inspiratory force > -25 cm H_2O . i.e. -20 or -15 etc....
- Minute ventilation < 4 L/min or > 10 L/min.

Types of Mechanical Ventilation:

A) Positive Pressure Ventilation (The most common)..... see later.

B) Negative Pressure Ventilation (Tank respirator).

- It does not require endotracheal intubation as negative pressure is applied to the abdomen and thorax to draw air into the lungs via the upper airway during inspiration. It is very rarely used. E.g. Cuirass ventilator (Iron lung).

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- Disadvantages:

- It can not overcome a substantial increase in airway resistance or a decrease in pulmonary compliance.
- It causes pooling of venous blood in the abdomen causing **tank shock**.

Positive Pressure Ventilation (Positive Pressure Ventilators)

Classification of Mechanical Ventilators:

Classically, there are three classes of ventilators:

	A) Pressure Limited (Controlled or Targeted)	B) Volume Limited (Controlled or Targeted)
Idea	These ventilators deliver a volume of air until a preset pressure is reached i.e. constant inspiratory pressure but variable volume .	These ventilators deliver a preset volume of air regardless of the opposing pressure i.e. constant volume but variable inspiratory pressure . N.B.; There is usually a pressure limit setting, that allows venting off excessive pressure to prevent barotrauma.
Parameters	<ul style="list-style-type: none"> • Tidal volume: - Variable. • Peak inspiratory pressure: - Constant. • Peak alveolar pressure: - Constant. 	<ul style="list-style-type: none"> - Constant (preset). - Variable. - Variable.
Indications	<ul style="list-style-type: none"> • Some neonatal ventilators. • Short term ventilations e.g. during transport. 	<ul style="list-style-type: none"> • They are the most common ventilators used in adults in the ICU. • OR ventilators.
Advantages	<ul style="list-style-type: none"> • They can compensate for a leak in the breathing circuit. • They protect against barotrauma. • They may recruit the collapsed alveoli. 	<ul style="list-style-type: none"> • They can deliver enough tidal volume if there is increased airway pressure e.g. circuit kink, obstruction, or bronchospasm.
Disadvantages	<ul style="list-style-type: none"> • They cannot deliver enough tidal volume if there is increased airway pressure e.g. circuit kink, obstruction, or bronchospasm. 	<ul style="list-style-type: none"> • They cannot compensate for a leak in the breathing circuit. • They may produce barotrauma.

C) Time Targeted Ventilators:

Gas flows into the lungs until a preset inspiratory time is reached.

N.B.; Recently; • New ventilators combine many of the qualities of the above classes.

- Microprocessor-Controlled Ventilators:
 - They can be set in a variety of inspiratory flow or cycling mechanisms and can also combine more than one mode.

Initial Ventilator Settings

Ventilator settings include;

1- Tidal Volume or Pressure Level:

- It is set according to the type of ventilation used, either volume controlled or pressure controlled.
- The selected (preset) Vt is affected by;
 - Compliance.
 - Resistance.
 - PaO₂.
 - PaCO₂.
 - and • Airway pressure.
- The usual preset Vt is 10-12 mL/Kg.

- The lower preset V_t at 4-10 mL/Kg is used in some cases to avoid volutrauma (stretched induced injury) and to decrease the plateau pressure ≤ 35 cm H₂O. This is the idea of **lung protective strategy in treatment of ARDs.**

2- Respiratory rate.

3- I: E ratio.

4- O₂ concentration.

5- Inspiratory flow rate (IFR):

- It is usually set at 40-90 L/min (60 L/min) in volume-targeted ventilators.

6- Inspiratory Flow Profile (Shape):

It may be square, sinusoidal, or decelerating ramp.

7- Trigger Sensitivity:

- It determines the start of inspiration.
- It is of 2 types;
 - a. Pressure Triggering: - The pressure is usually set at -0.5 to -1.5 cm H₂O.
 - When it is adjusted to be too sensitive i.e. -0.5, this produces self cycling.
 - When it is adjusted to be too insensitive, this increases the work of breathing.
 - b. Flow Triggering: Instead of generating -ve pressure, the inspiratory flow produced by the patient will cause and initiate the ventilator to provide fresh gas to the breathing circuit.

8- Mode of Ventilation:

Its choice depends on the need of either full or partial ventilatory support by the patient.

a. Full Ventilatory Support:

E.g. CV, A/C, and SIMV (with a high rate).

b. Partial Ventilatory Support (Assisted Modes of Ventilation):

E.g. SIMV (with low rate).....see later.

These modes allow; • Spontaneous breathing during mechanical ventilation that preserves the CO.

- More ventilation-perfusion matching.

9- Periodic Sigh Breaths: (Periodic Large Tidal Volume).

N.B.; **Physiologic PEEP:** Addition of 5 cm H₂O of PEEP during +ve pressure ventilation preserves the FRC and gas exchange to compensate for the loss of intrinsic PEEP after intubation.

If physiologic PEEP + a large V_t 10-12 mL/kg are used, there is no need for periodic sigh breaths.

N.B.; Avoid changing more than one ventilator parameter at a time.

The aim of IPPV:

A- To Maintain Adequate Oxygenation (SaO₂ > 95%) with a FiO₂ of < 0.5:

- Arterial oxygenation is controlled by;

1- **FiO₂:** Initially it is adjusted at 40% (may be 50% in severe hypoxic patients). Avoid higher concentrations > 50-60% to avoid the risk of O₂ toxicity. Then after 10 min, AB gases are repeated to readjust the FiO₂.

2- **PEEP**.....See later.

3- **IRV**.....See later.

4- **Pressure Support**.....See later.

B- To Maintain the PaCO₂ at a Satisfactory Level:

- The aim is to produce **gradual changes** in the PaCO₂ until an adequate satisfactory level is reached.

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- CO₂ tension is controlled by;

The minute ventilation = RR x tidal volume.

Increasing the tidal volume usually decreases the PaCO₂ more than increasing the respiratory rate. The latter may also cause respiratory alkalosis.

- CO₂ tension: is adjusted as follows:

- Patients with a **normal PaCO₂** before IPPV; adjust minute ventilation to produce a PaCO₂ between **30-35 mm Hg**.
- Patients with an initial **high PaCO₂** before IPPV; the PaCO₂ should be **reduced at a rate < 7.5 mm Hg (1kpa)/hr**, because rapid reduction produces a marked fall in the CO and ABP.
- Patients with an initial **chronically high PaCO₂** (e.g. chronic bronchitis), the PaCO₂ should be reduced **at the same rate** and should **not** be reduced **below 40-45 mm Hg**.
- Patients with a **low PaCO₂ < 30 mm Hg** before IPPV, adjust minute ventilation to **increase the PaCO₂ slowly** by controlling the RR. Further adjustment should be done after one hour.

Modes of Ventilation

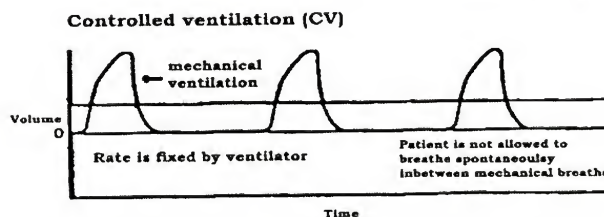
Definition: (of mode):

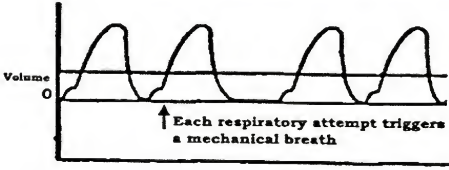
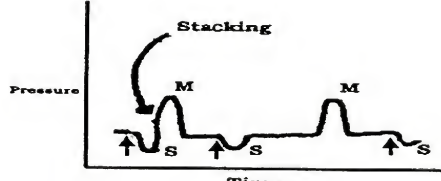
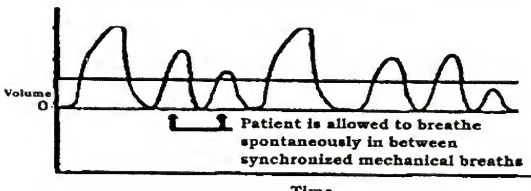
It is the method with which the ventilation cycles from expiration to inspiration and whether the patient is able to breathe spontaneously or not.

It includes;

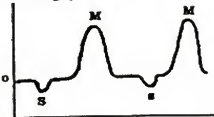
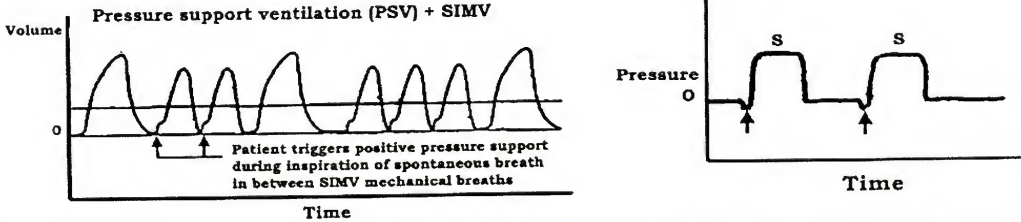
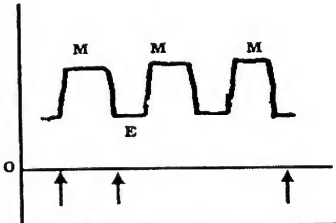
- 1- CV → Controlled Ventilation.
- 2- A/C → Assist-Controlled Ventilation.
- 3- IMV → Intermittent Mandatory Ventilation.
- 4- SIMV → Synchronized IMV.
- 5- MMV → Mandatory Minute Ventilation.
- 6- PSV → Pressure Support Ventilation.
- 7- IRV → Inverse I: E Ratio Ventilation.
- 8- APRV → Airway Pressure Release Ventilation.
- 9- BiPAP → Biphaseic Positive Airway Pressure Ventilation.
- 10- DLV → Differential Lung Ventilation.
- 11- HFV → High Frequency Ventilation.

Mode	Characters	Remarks
1- CV	<p>- It is either;</p> <ul style="list-style-type: none"> • Volume targeted CV where preset Vt and RR are set. i.e. it provides a fixed Vt and a fixed RR. • Pressure targeted CV where preset peak pressure and RR are set. <p>- The patient is passive i.e. completely paralyzed.</p>	<p>Advantages:</p> <ul style="list-style-type: none"> • It allows guaranteed Vt or peak pressure. • It rests the respiratory muscles. <p>Disadvantages:</p> <ul style="list-style-type: none"> • It may lead to respiratory muscle dysfunction due to complete rest of the muscles, so it is not used nowadays in ICU. • It usually needs heavy sedation ± muscle paralysis.



2- A/C	<p>- It is either;</p> <ul style="list-style-type: none"> • Volume targeted A/C where a minimum preset fixed V_t and RR are set. • Pressure targeted A/C where peak pressure and RR are set. <p>- The patient is either passive i.e. completely paralyzed or active i.e. the patient can increase the RR by producing sufficient magnitude of inspiratory effort, which is detected by a pressure sensor to trigger additional inspiration. Trigger sensitivity is usually -1 to -2 cm H_2O.</p>	<p>Advantages:</p> <ul style="list-style-type: none"> • Less work is needed. • The sensitivity of the pressure sensor can be adjusted so, if spontaneous inspiratory efforts are not detected the machine functions as if it is in CV mode <p>Disadvantages:</p> <ul style="list-style-type: none"> • Patient/ventilator asynchrony. • Respiratory muscle dysfunction. • Air trapping in COPD.
	<p style="text-align: center;">Assist-controlled ventilation (AC)</p> 	
3- IMV	<p>- It is either;</p> <ul style="list-style-type: none"> • Volume targeted IMV where a minimum V_t and RR are set to supplement spontaneous breathing patients. • Pressure targeted IMV where a minimum peak pressure and RR are set. <p>- At a high mandatory rate of 10-12 breaths/min, IMV essentially provides all of the patient's ventilation, as in cases where no spontaneous breathing is expected from the patient, while at low rates of 1-2 breaths/min, it provides minimal mechanical ventilation in case where spontaneous breathing of the patient is good preserved.</p> <p>- The patient is active.</p>	<p>Advantages:</p> <ul style="list-style-type: none"> • It is one of the weaning modes. • A low mean airway (intra-thoracic) pressure is produced; less than with CV and A/C, causing less CVS effects, less pulmonary barotrauma and allowing the use of high levels of PEEP. • There is a decreased need for sedation and no muscle relaxant is needed. <p>Disadvantages:</p> <ul style="list-style-type: none"> • Patient/ventilator asynchrony as stacking may occur.
		
4- SIMV	<p>- It is either; Volume targeted or Pressure targeted SIMV.</p> <p>- As IMV....., but it times the mechanical breath whenever possible to coincide with the beginning of spontaneous effort so, preventing superimposing (stacking) a mechanical breath, in the middle of a spontaneous breath, that may produce a very large tidal volume.</p>	<p>Advantages:</p> <ul style="list-style-type: none"> - As IMV (weaning mode and decrease airway pressure) + - It avoids stacking, allowing more patient comfort and patient/ventilator synchrony. <p>Disadvantages:</p> <ul style="list-style-type: none"> • Increased work of breathing. • Increased O_2 consumption.
	<p style="text-align: center;">Synchronized intermittent mandatory ventilation (SIMV)</p> 	
5- MMV	<p>- A minimum preset minute ventilation is set. The ventilator monitors the exhaled minute ventilation so, the machine then continuously adjusts the number of mechanical breaths. The patient's actual minute ventilation must meet or exceed the set target. If the patient's spontaneous minute ventilation is below the target, A/C breaths are delivered to reach the desired set minute ventilation. If the patient becomes apneic, the ventilator provides controlled ventilation, whereas, if the patient can provide the total target minute ventilation without support, no ventilator breathes are delivered.</p>	<p>Advantages:</p> <ul style="list-style-type: none"> • It is one of the weaning modes. <p>Disadvantages:</p> <ul style="list-style-type: none"> • It does not monitor alveolar ventilation (rapid or shallow)

INTENSIVE CARE

	<p>The sum of spontaneous breathes + mechanical breathes = the desired set minute ventilation.</p> <p>- The patient is active i.e. a spontaneously breathing patient.</p> 	
6- PSV	<p>- A predetermined +ve inspiratory pressure is set to help the patient's inspiratory effort. When the patient makes the initial inspiratory effort, a very sensitive pressure transducer detects the slight negative pressure change, and application of a constant support pressure is begun. Pressure is applied continuously throughout inspiration at the value selected by the operator.</p> <p>- It can be adjusted at either;</p> <p>a. Low levels of PSV (5-15 cm H₂O): It can be added to other modes to overcome any increase in inspiratory resistance from ETT, breathing circuits as tubing, connectors, and humidifiers.</p> <p>b. High levels (20-40 cm H₂O): It can be used as stand-alone ventilatory mode in spontaneously breathing patients, as it may give a tidal volume of about 10 mL/Kg</p> <p>- In many of the new ventilators, 2 additional variables can be controlled;</p> <p>a. The Inspiratory Time: It controls the speed with which peak flow is established. The rise time can be set to insure establishment of peak flow within 100 milliseconds of the start of the breath.</p> <p>b. The Expiratory Sensitivity: It adjusts the end inspiratory flow at which expiration is triggered i.e. it allows the clinician to actually set flow that terminates inspiration</p> <p>- The patient is active i.e. a spontaneously breathing patient.</p> <p>Advantages:</p> <ul style="list-style-type: none"> • It is one of the weaning modes. • It decreases work of breathing. • A low mean airway (intra-thoracic) pressure less than CMV and A/C is produced, causing less CVS effects and less pulmonary barotrauma and allows the use of high levels of PEEP. • There is a decreased need for sedation and no muscle relaxant is needed. <p>Disadvantages:</p> <ul style="list-style-type: none"> • It is unsuitable in the absence of adequate respiratory drive, if used alone. 	
7- IRV	<p>- It reverses the normal inspiratory to expiratory time ratio to more than 1:1. A ratio of 2:1 is usually used.</p> <p>- It may be applied with other modes (volume or pressure targeted modes).</p> <p>- The patient is passive i.e. completely paralyzed.</p> <p>Advantages:</p> <ul style="list-style-type: none"> • it is very useful in ARDs patientssee respiration. <p>Disadvantages:</p> <ul style="list-style-type: none"> • It requires heavy sedation or muscle paralysis. • Intrinsic PEEP occurs because each new breath begins before the complete exhalation of the last, causing air trapping that increases the FRC until a new equilibrium is reached. • It can cause pulmonary barotrauma. 	

8- APRV	<p>- In which the following are set;</p> <ul style="list-style-type: none"> • Two pressure levels; A minimum high CPAP (usually start with 10-15 cmH₂O) and a release level (usually start with 5-10 cmH₂O) i.e. There is periodic release of the high CPAP to a lower level of +ve pressure to allow exhalations i.e. Bi-level airway pressure. The airway pressure decreases with both the spontaneous inspiration and mechanical exhalation. • Inspiratory time (usually start with 3-5 seconds). The inspiratory time determines the mechanical RR. • Expiratory time (usually start with 1.5-2 seconds). - The patient is active i.e. a spontaneously breathing patient. 	<p><u>Advantages:</u></p> <ul style="list-style-type: none"> • Less hemodynamic effects (less circulatory depression). • Less barotrauma. • It has a role in ARDs patients. • Spontaneous breathing at either level is possible. • The timing of transition from one pressure level to the other pressure level will be synchronized with the patient's breathing.
9- BiPAP	<p>- It is pressure controlled ventilation. It is a modification of APRV. In which the following are set;</p> <ul style="list-style-type: none"> • Two pressure levels i.e. Bi-level CPAP (P_H and P_L). • Inspiratory time at P_H, and expiratory time at P_L, or T_H/T_L ratio. • Flow acceleration percentage (rise % or rise time) is set at both pressure levels. It tailors the inspiratory rise to match patient demand. • Expiratory sensitivity (E_{sens}) is set at both pressure levels. - It can be used alone (Genuine-BiPAP) or combined with other modes; • Pressure support can be added at both pressure levels. • CV-BiPAP: No spontaneous breathing is allowed. • IMV-BiPAP: Spontaneous breathing is allowed at the lower CPAP level. • APRV-BiPAP: Spontaneous breathing is allowed at the upper CPAP level. <p><u>Bi PAP with low pressure support</u></p>	<p><u>Advantages:</u></p> <p>As APRV.</p> <p>It is one of the modes of weaning.</p>

N.B.; Assisted Modes of Ventilation:

They allow spontaneous breathing during mechanical ventilation i.e. **the patient is active**.

They include; 1- A/C.

2- IMV (with low RR).

3- SIMV (with low RR).

4- MMV (with low minute ventilation).

5- PS.

6- APRV.

7- BiPAP.

N.B; Patient-Ventilator Synchrony

- It is matching a patient's demand and ventilatory pattern without imposing some effort or increasing the patient's work.
- To date, there is no ventilatory mode available that can perfectly produce patient-ventilatory synchrony.
- **Factors Causing Patient-Ventilatory Asynchrony:**
 - 1- Setting/response of the ventilator.
 - 2- Changes in patient/ventilatory demand.
 - 3- Problem with the artificial airway.
 - 4- Changes in pathophysiology.
- Many modes have been tried to allow patient-ventilator synchrony. They are called Assisted modes of ventilators.

10- Differential Lung Ventilation (DLV):

Independent Lung Ventilation (ILV)

After separation of the lungs with a **double lumen endotracheal tube**, differential +ve pressure with one or two ventilators is applied to each lung independently. If 2 ventilators are used, the timing of mechanical breaths usually is synchronized.

Uses: Patients with **severe unilateral lung disease** that is refractory to PEEP.

11- High Frequency Ventilation (HFV):

a- High Frequency Positive Pressure Ventilation (HFPPV):

It delivers a small preset conventional tidal volume i.e. 2-3 mL at a rate of **60-110 breaths/min**.

Active inspiration + passive expiration + no entrainment.

- Advantages:**
- Lower airway pressure.
 - Less circulatory interference than in IPPV.

b- High Frequency Jet Ventilation (HFJV):

It utilizes a small cannula at or in the airway through which gas is injected at **110-400 times/min**.

Active inspiration + passive expiration + entrainment.

Gas entrainment (Bernoulli effect) may augment the tidal volume.

c- High Frequency Oscillation (HFO):

It employs a rotatory driven piston that creates to - and fro-gas movements in the airway at rates of **400-3000 times/min**.

Active inspiration + active expiration + no entrainment.

Disadvantages:

- 1- **Inadequate heating and humidification of inspired gases** during prolonged HFV, may cause hypothermia and tracheo-bronchitis.
- 2- An **intrinsic PEEP** is seen during HFJV at high drive pressures and inspiratory times > 40% so, it is **contraindicated in COPD**.

Uses:

a- In the OR:

- For **laryngeal, tracheal, and bronchial** procedures.
- For **emergency management of the airway** when endotracheal intubation and conventional +ve pressure ventilation are unsuccessful.
- **Open thoracic surgery** due to a moderately expanded lung and minimal respiratory movement produced with HFV.

b- In the ICU: When conventional ventilation has failed in the following cases;

- **Broncho-pleural and tracheo-esophageal fistulas.**

- Persistent fetal circulation in neonates (to help CO₂ elimination).
- Respiratory failure.
- Adult and infant ARDs.
- Barotrauma.

Tracheal Gas Insufflation (TGI)

Definition:

- It is the introduction of a secondary, low to moderate, **continuous or phasic flow** of fresh gas, near the carina, to washout the CO₂ in the anatomic dead space before the next inspiration.
- TGI is intended to wash the anatomical and mechanical dead space of CO₂ during exhalation, thus diluting alveolar PaCO₂ during inspiration and decreasing the PaCO₂ so, it is effective in ARDS.

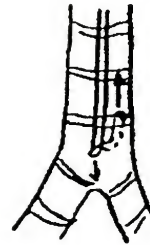


Figure 38-1; TGI

Types of TGI: (figure 38-1)

1- Direct flow TGI:

- The injected flow is **directed towards the carina**. It is **more efficient** than the indirect type.
- Disadvantage: It inhibits the expiratory flow so may produce PEEP.

2- Indirect (inverse) flow TGI:

- The injected flow is **directed towards the mouth**.
- It produces negative pressure at the site of the catheter, that produces a jet drag effect reducing the PEEP level.

Uses: ARDS as an adjunct to decrease the PaCO₂.

Positive Airway Pressure Therapy

Indication:

Patients with symptomatic decrease in the FRC, resulting in absolute or relative hypoxemia. Patients either breathe spontaneously or with mechanical ventilation.

Mechanism of Action (Advantages):

It improves oxygenation by increasing the trans-pulmonary distending pressure which causes;

1- Increased Lung Volumes:

- **Increased FRC:** in a linear relationship, as FRC increases by 400 cc for each 5 cm H₂O increase in pressure.
- **Increased PEEP level** that produces **recruitment** i.e. expansion of collapsed alveoli during expiration.
- **Increased tidal volume:** above the closing capacity.

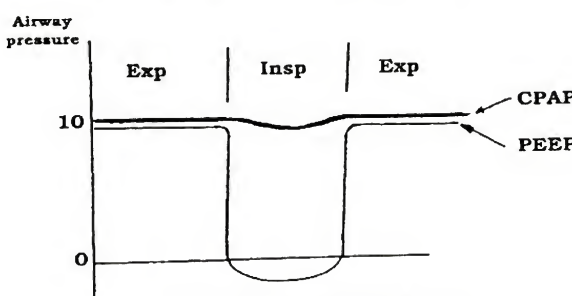
2- Increased (and improved) Lung Compliance in the diseased lung.

3- Reverse Ventilation/Perfusion Mismatching: This decreases venous admixture, and thus improves arterial oxygenation.

4- Redistribution of Interstitial Pulmonary H₂O:

This occurs from the less compliant areas (between alveolar epithelium and capillary endothelium, where gas exchange occurs) to the more compliant areas (peri-bronchial and hilar areas). It does not decrease the total extra-vascular lung H₂O content).

INTENSIVE CARE**Types:**

	Positive End-Expiratory Pressure (PEEP)	Continuous Positive Airway Pressure (CPAP)
	 <p style="text-align: center;">Figure 38-2; PEEP and CPAP</p>	
Definition	The positive pressure is applied only during expiration (figure 38-2).	The positive pressure is applied during both inspiration and expiration (figure 38-2).
Character	<ul style="list-style-type: none"> - It is used when the patient is on mechanical ventilation as CV, A/C, SIMV, and PCV. - The inspiratory work of breathing is increased in direct proportion to the level of PEEP. 	<ul style="list-style-type: none"> - It is used when the patient is spontaneously breathing. a- In alert and conscious patients with intact airway reflexes (i.e. without ETT), CPAP level should be < 15 cm H₂O (i.e. less than the lower esophageal sphincter pressure). It is applied by either CPAP face mask or CPAP nasal mask. b- In comatose patients, with poor airway reflexes CPAP levels > 15cm H₂O is needed, or artificial airway (ETT) is essential due to the risk of gastric distention and regurgitation. - The inspiratory work of breathing is decreased, but at the expense of a higher mean airway pressure.

Disadvantages (Complications) of CPAP and PEEP:**a- Pulmonary:**

1- Excessive PEEP or CPAP cause over-distended alveoli (and bronchi) that results in;

- Increased dead space.
- Decreased lung compliance.

Both increase the work of breathing.

2- Increased incidence of pulmonary barotrauma especially when CPAP or PEEP are > 20 cm H₂O. This causes disruption of alveoli, and allows the air to leak interstitially, along bronchi, into;

- The mediastinum → pneumo-mediastinum.
 - The pleural space → pneumothorax.
 - The pericardium → pneumo-pericardium.
 - Dissect along tissue planes s.c → subcutaneous emphysema.
 - The abdomen → pneumo-peritoneum or pneumo-retro-peritoneum.
- Failure of an air leak to seal causes a broncho-pleural fistula.

Q: What are the pulmonary effects of PEEP and CPAP?

A: Discuss: Mechanism of action + pulmonary complications.

b- Non-Pulmonary Complications:

It is mainly due to transmission of increased airway pressure to the contents of the chest. Fortunately, transmission is directly related to lung compliance thus patients with decreased lung compliance (most patients requiring PEEP) are the least effected.

1- Decreased CO:

- CO decreases progressively with a progressive increase in the mean airway pressure i.e. CO is inversely proportionate to PEEP. This is because a PEEP of $> 15 \text{ cm H}_2\text{O}$ causes;
- A progressive **decrease** in VR (mainly).
- Compresses alveolar capillaries, thus **increasing pulmonary vascular resistance** that in turn increases RV afterload (due to over-distension of alveoli). RV dilatation causes left ward displacement of the inter-ventricular septum that interferes with LV filling so, both the SV and CO are decreased.

2- Decreased Hepatic Blood Flow due to decreased CO and increased CVP.**3- Renal:**

- Decreased renal blood flow due to decreased CO and increased CVP.
- Decreased GFR free water clearance and UOP.
- + Increased angiotensin level and ADH level.

4- Increased IC Hypertension due to increased CVP.**Types of PEEP:****1- Optimal (Best) PEEP:****a- Optimal (Best) Conventional PEEP:**

- It is the level of PEEP with the highest O_2 supply, and above which the detrimental effects of PEEP overshadow any beneficial effects.

$$\text{O}_2 \text{ Flux} = \text{O}_2 \text{ supply} = \text{CO} \times \text{Arterial O}_2 \text{ content.}$$

PEEP decreases the CO and increases, arterial O_2 content up to a limit, after which O_2 flux is decreased. If O_2 consumption is not changed, O_2 content is less in blood returning to the heart resulting in decreased O_2 concentration in mixed venous blood.

- The optimal PEEP or CPAP is usually below 15- 20 cm H_2O .

b- Optimal (Best) High or Super-PEEP:

- It is the level of PEEP with the lowest intra-pulmonary shunt and without compromising the CO.

- It is usually $> 25 \text{ cm H}_2\text{O}$.

Recently, the Optimal (Best) Clinical PEEP:

- It is the lowest level of PEEP that provides an adequate PaO_2 at an FiO_2 of < 0.5 . So, increasing PEEP to reach the best conventional or the best high PEEP is not clinically helpful nowadays.

- Practically, PEEP is usually added in increments of 3-5 cm H_2O until the desired therapeutic end point is reached.

- a- The most commonly suggested end point is an arterial O_2 saturation of $> 90 \%$ on a non-toxic FiO_2 ($\leq 50\%$), some prefer a lower FiO_2 .

- b- Some use the calculated venous admixture as an end point, because a shunt $< 15\%$ usually causes an acceptable O_2 tension on a non-toxic FiO_2 ($\leq 50\%$).

- c- Some prefer lung compliance or dead space monitoring.

2- Prophylactic (Physiologic) PEEP:

- It is 1-5 cm H_2O , to increase the FRC above the closing volume.

3- Conventional PEEP:

- It is 6-20 cm H_2O , when the PaO_2 is $< 60 \text{ mm Hg}$, with a FiO_2 of > 0.5 .

4- High PEEP:

- It is $> 20 \text{ cm H}_2\text{O}$.

- It is used when extreme hypoxemia, not responding to conventional PEEP, is present.

5- Intrinsic PEEP (Auto-PEEP): See before.**6- Liquid (Fluid) PEEP: See artificial blood substitutes.**

Other Techniques Adjunct to Ventilatory Support

1- Aerosolized Water:

- An aerosol mist is a gas or gas mixture containing a suspension of liquid particles.
- It is used to **loosen inspissated secretions & facilitate their removal** from the tracheo-bronchial tree.

2- Aerosolized Bronchodilators, Mucolytics, and Vasoconstrictors:

- They are usually aerosolized in 2-3 mL of saline.
- **Effective cough** is always necessary and may be produced by;
 - Adequate inspiratory capacity.
 - An intact glottis.
 - Adequate muscle strength (abdominal muscle and diaphragm).

3- Chest Physiotherapy:

Including chest percussion, vibrating therapy, or postural drainage of various lung lobes.

4- Nasopharyngeal, Endotracheal or Bronchoscopic Suction of Secretions.

5- Maneuvers Producing Sustained Maximum Lung Inflations:

- E.g. Incentive spirometer: Value:
 - Induces cough.
 - Prevents atelectasis.
 - Preserves normal lung volumes.
- Patients can sustain at least one liter lung inflation, which is usually able to produce effective coughing.

6- Liquid Ventilation:

- See artificial blood substitutes.

7- Prone Position Ventilation:...

8- Nitric Oxide Inhalation:

9- Permissive Hypercarbia: See before ARDs (anesthesia with respiratory disease).

10- ECMO:

Care (Management) of Patients Requiring Mechanical Ventilation

1- Endotracheal Intubations:

- Both nasal and oral (trans-laryngeal) endotracheal intubations are relatively **safe for 2-3 weeks**. If prolonged periods are required, sub-glottic stenosis may occur, so it should be replaced by a cuffed tracheostomy tube if > 2-3 weeks period is needed.
- **Nasal intubation is preferred** for prolonged intubations (than the oral route) as it is:
 - More comfortable for the patient.
 - More secure (less risk of accidental extubation).
 - Causes a less risk of laryngeal edema.

Disadvantage of nasal intubations:

- Significant nasal bleeding.
- Transient bacteremia.
- Submucosal dissection of the nasopharynx or oropharynx.
- Sinusitis or otitis media (from obstruction of the auditory tubes).
- The time of ETT intubation and initiation of mechanical ventilation is usually associated with a great hemodynamic instability as hyper- or hypotension, brady- or tachycardia. This is due to:
 - Autonomic reflexes from stimulation of the airway.
 - Myocardial depression and VD from sedative-hypnotic agents.

- Straining by the patient.
- Withdrawal of intense sympathetic activity.
- Decreased VR due to +ve airway pressure.

So, careful monitoring is required during and immediately after intubation.

2- Sedation and Paralysis:

Indications:

- **During intubation** in vigorous and uncooperative patients.
- **Agitated patients who fight the ventilator**, because repetitive coughing (bucking) and straining may have adverse hemodynamic effects, can interfere with gas exchange, and may predispose to pulmonary barotrauma.
- During SIMV when patients continue to be tachypneic in spite of high mechanical respiratory rates ($> 16-18$ breaths/min), excessive rapid spontaneous respiration (> 30 breaths/min) is required, which increases the work of breathing.

By: i.v. infusions of one of or a combination of;

- | | |
|--|---------------|
| • Opioids (morphine, fentanyl)..... | } → Sedatives |
| • Benzodiazepines (diazepam, midazolam)..... | |
| • Propofol..... | |
| • Non-depolarizing muscle relaxants..... | → Paralysis. |

3- Monitoring:

- 1- Continuous **ECG and pulse oximetry**.
- 2- **Arterial cannula** for invasive ABP and repeated AB gases.
- 3- **Fluid balance record** (intake and output) so, **urinary catheterization**.
- 4- **CVP and PAP** in hemodynamically unstable patients.
- 5- **At least a daily chest X-ray** to assess the following:
 - ETT position.
 - Evidence of pulmonary barotrauma.
 - Fluid balance.
 - Progression of pulmonary disease.
- 6- Airway pressures (peak, baseline, and mean).
Exhaled tidal volume (mechanical and spontaneous).
FiO₂.

These are necessary to allow optimal adjustment of ventilator settings.

- An increase in the peak inflation pressure and a decrease in the exhaled V_t, indicate the presence of large mucus plugs and presence of airway secretions.
- Abrupt increase in peak inflation pressure + sudden hypotension, indicate pneumothorax.

Complications of Mechanical Ventilation

I) Respiratory Complications:

1- Hypo- or Hyperventilation:

They cause respiratory acidosis or alkalosis respectively.

2- Complications of Excessive Pressure and Flow Rates:

a- Pulmonary Barotrauma:

- **Causes:** Barotrauma occurs when the total lung capacity (TLC) is exceeded and **trans-alveolar pressure** becomes $\geq 30-35$ cm H₂O (the trans-alveolar pressure is the difference between the alveolar pressure and the pleural pressure).

- Risk Factors:

- PEEP > 15 cm H₂O.
- PIP $> 40-50$ cm H₂O.
- V_t > 15 mL/Kg.

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- Complications: Gas may escape producing;
 - Pneumothorax.
 - Mediastinal or s.c. emphysema.
 - Pneumo-pericardium or pneumo-peritoneum.
 - Systemic air embolism.
 - Broncho-pleural fistula.
- Prevention:
 - Avoid risk factors.
 - Allow permissive hypercarbia.
 - Use PCV or HFV.

b- Pulmonary Volutrauma:

- Many researches, especially in ARDS lungs, prove that **over-distention of alveoli i.e. volutrauma**, and not high pressures i.e. barotrauma, is the cause of lung injury.
- But because the volume of the individual alveolus cannot be practically determined, the trans-alveolar pressure is used as a surrogate.

c- Shear Stress:

- In ARDS, diseased alveoli may collapse during early to mid-exhalation and may open late during mid-to late inspiration.
- This **cyclical opening and closing of alveoli** results in a **shearing stress** that may result in volutrauma.
- UIP and LIP.....see anesthesia with respiratory diseases.

3- Patient/Ventilator Asynchrony:

- The patient may fight the ventilator producing hypoxia, respiratory distress, and increased work of breathing.....see before.

4- Ventilator Malfunction:

- May occur due to machine failure, electrical failure, alarm failure, or humidifier failure.

5- Ventilator Associated Pneumonia:

- Cause: Pseudomonas aeruginosa, Staphylococcus aureus, Enterobacter species, Klebsiella pneumoniae, or Haemophilus influenza.

- Risk Factors:

- Poor nutrition.
- Intubation.
- Immobility.
- Impaired consciousness.
- Epidemiologically significant pathogens.
- Gastric Colonization.

- Prevention:

- An aseptic technique is used during dealing with ventilated patients and other patients e.g. wearing gowns, masks, and eye covers.
- Hand-washing for 10 seconds with an antimicrobial agent is the most critical factor in prevention of all noso-comial infections.
- Avoid the risk factors.

6- Complications of Tracheal Intubation:

See before.....

Q: Discuss ventilator induced lung injury?

II) CVS Complications:**1- Effect of Increased Intrathoracic Pressure and PEEP:**

Decreased CO and hypotensionsee above.

2- Prolonged Bed Recumbency:

It may cause DVT and pulmonary embolism.

III) O₂ Toxicity:

If FiO_2 is > 0.6See its effects.

IV) Renal Complications:

Increased intra-thoracic pressure decreases the CO that in turn decreases RBF, GFR, and UOP.

V) Nutritional Problems:

1- Increased Caloric Requirements: Due to the hyper-catabolic state.

2- Increased PaCO₂: Due to increased carbohydrate load.

VI) Psychologic Trauma:

Patients feel fear, and anxiety, from never being able to get off the ventilator.

VII) Side Effects of Adjuvant Drugs Used:

As morphine, benzodiazepines, neuromuscular blockers.

Weaning From Mechanical Ventilation:

The ease of weaning a patient from a ventilator is generally inversely related to the duration of the mechanical ventilation.

Before weaning: the following should be considered (**Criteria of Weaning**).

1- The process that necessitated mechanical ventilation must be reversed or under control before weaning is attempted i.e. patients **no longer meet indications for mechanical ventilation** and must have the following criteria (= criteria for prediction of outcome).

a- Respiratory Gas Tension:

- Direct Indices:

- $\text{PaO}_2 > 60$ mm Hg (or $\text{SaO}_2 > 90\%$) with $\text{FiO}_2 < 0.5$, with < 5 cm H₂O PEEP.
- $\text{PaCO}_2 < 50$ mm Hg except if the patient has chronic hypercarbia.

- Derived Indices:

- $\text{PaO}_2 / \text{FiO}_2$ ratio > 200 mm Hg.
- PA- a O₂ gradient $< 300-350$ mm Hg at $\text{FiO}_2 1.0$ or < 200 mm Hg at $\text{FiO}_2 0.5$
- $\text{Vd/Vt} < 0.6$
- $\text{Qs/Q}_T < 15\%$

b- Respiratory Rate: $< 30-35$ breath / min in adults

Both the AB gases and respiratory rate are the most useful criteria.

c- Respiratory Mechanics:

- Tidal volume > 5 mL/Kg.
- Vital capacity $> 10-15$ mL/Kg.
- Maximum inspiratory force (inspiratory pressure) < -25 cm H₂O i.e. -35, -40 etc.....
- Minute ventilation 4-10 L/min.

2- **Correction of factors** that may complicate weaning;

- As
- | | | |
|--|------------------------|----------------------|
| * Bronchospasm. | * Malnutrition. | * Anemia. |
| * Infection. | * Metabolic alkalosis. | * Sleep deprivation. |
| * Increased CO ₂ production due to high carbohydrate loads. | | |
| * Hypothermia or hyperthermia. | | |

3- **Sensorium:** Fully conscious, alert and cooperative with intact reflexes.

4- **Hemodynamic stability.**

5- **Underlying lung disease and respiratory muscle wasting** should be absent.

Techniques of Weaning:

1- **SIMV (or IMV):**

- The number of mechanical breaths is progressively decreased by 1-2 breaths/min as long as the PaCO₂ and RR remain acceptable i.e. < 45 mm Hg and < 30 breath/min

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respectively, allowing the patient to slowly take over spontaneous ventilation. When SIMV of 1-2 breaths/min is reached, mechanical ventilation is discontinued.

- It is the least efficient mode of weaning because it promotes dependence on the ventilator and can be confusing to the respiratory center.

N.B.: • In patients with acid-base disturbances or chronic CO₂ retention, arterial blood pH (>7.35) is more useful than CO₂ tension monitoring. Blood gas measurements should be checked after a minimum of 10-20 minutes at each setting.

• If pressure support is concomitantly used with SIMV, it should be reduced (see later).

2- PSV:

- Gradually decrease the PS level by 2-3 cm H₂O (with the same criteria of PaCO₂ and RR as with SIMV). When a PS level of < 5-8 cm H₂O is reached, the patient can be extubated.

- It can be combined with SIMV or with CPAP.

3- T-piece Trials:

- It has the **highest success rate** because there is no physician bias but only the patient is the sole controller.

- When the patient meets the criteria for weaning, a T-piece adaptor and heated nebulizer are connected to the patient's ETT. The patient should be in a semi-sitting position. FiO₂ is set at a level 5-10% higher than that during mechanical ventilator.

- **Try 3-8 trials/day. In them, allow the patient to breathe spontaneously** without any mechanical breaths. The patient is observed closely during this period (usually 10-20 min) for:

- Signs of fatigue, chest retraction, tachypnea, marked tachycardia, arrhythmias and hypertension.

- Bad AB gases after 10-20 min.

If the above are present, discontinue weaning.

If the patient has been intubated for a prolonged period, or has a severe underlying lung disease, T-piece trials are done in periods of 10-20 min which progressively increase by 5-10 minutes/hour until the patient appears comfortable and shows acceptable AB gases.

N.B.: The T-piece attaches directly to the ETT or tracheostomy tube and has corrugated tubing on the other two limbs. A humidified O₂-air mixture flows into the proximal distal limb and exits from the distal limb. Sufficient gas flow must be given in the proximal limb to prevent the mist from being completely drawn back at the distal limb during inspiration. This ensures that the patient is receiving the desired O₂ concentration.

4- CPAP:

- Use low levels (5 cm H₂O) while the patient breaths spontaneously (instead of the T-piece) because:

1- It maintains the FRC.

2- It prevents atelectasis which can occur during prolonged T-piece trials, due to absence of a normal physiologic PEEP, when the larynx is bypassed by an E.T.T.

Also, the patient is observed clinically for signs of fatigue and respiratory distress and AB gases are done as with the T-piece.

5- BiPAP:

- Weaning is done by decreasing the ventilation pressure until the difference between the P_{high} and P_{low} is 5 cm H₂O.

Q: What are the new techniques for ventilation and oxygenation?

A: 1- New ventilator modes as MMV, SIMV, PSV, IRV, APRV, BiPAP, HFV, Differential lung ventilation..

2- Protective lung strategy as permissive hypercarbia, decreased RR...See anesthesia with ARDS.

3- Liquid ventilation.

4- Prone position ventilation.

5- ECMO for CO₂ removal and improvement of oxygenation.

6- Apneic oxygenation.

7- Tracheal gas insufflation.

SIRS, Septic Shock, and MODS

Definition:

(Suggested by the American college of chest physicians / society of critical care medicine consensus conference)

Systemic Inflammatory Response Syndrome (SIRS):

- It is the **response to severe infectious and non-infectious illness** characterized by more than one (i.e. ≥ 2) of the followings;

- Temperature $> 38^{\circ}\text{C}$ or $< 36^{\circ}\text{C}$.
- HR > 90 beat/min.
- RR > 20 breath/min.
- Or $\text{PaCO}_2 < 32$ mm Hg.
- WBC $> 12000/\text{mm}^3$ leukocytosis.
 $< 4000/\text{mm}^3$ leukopenia.

Or $> 10\%$ immature (band) forms.

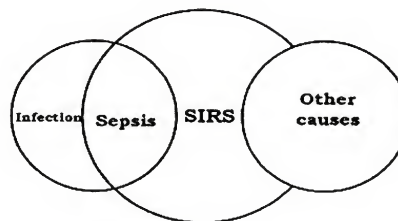
- Causes of SIRS:

1- Severe infection as bacterial, viral.....etc.

2- Non-infectious illness.....the same causes of secondary ARDS....see before.

- **The relationship between infection, sepsis and SIRS**

(figure 38-3).



Sepsis:

-It is the systemic inflammatory response to infection.

Severe Sepsis:

- It is sepsis associated with either;

- Organ dysfunction
- Hypotension
- Hypoperfusion i.e. lactic acidosis, oliguria and acute alteration of mental status.

Shock:

- **Insufficient flow of nutrients to tissues** or tissue under perfusion and/or ineffective use of energy substrates at the cellular level.

Septic Shock:

- **It is sepsis with hypotension (systolic ABP < 90 mm Hg) despite adequate fluid resuscitation along with the presence of hypo-perfusion.**

Sterile Shock:

- It is severe SIRS due to non-infectious causes without demonstrable infection.

Multiple Organ Dysfunction Syndrome (MODS):

- It is **progressive dysfunction of 2 or more organs** (usually associated with severe sepsis) **in an acutely ill-patient**, in whom, homeostasis can not be maintained without intervention.

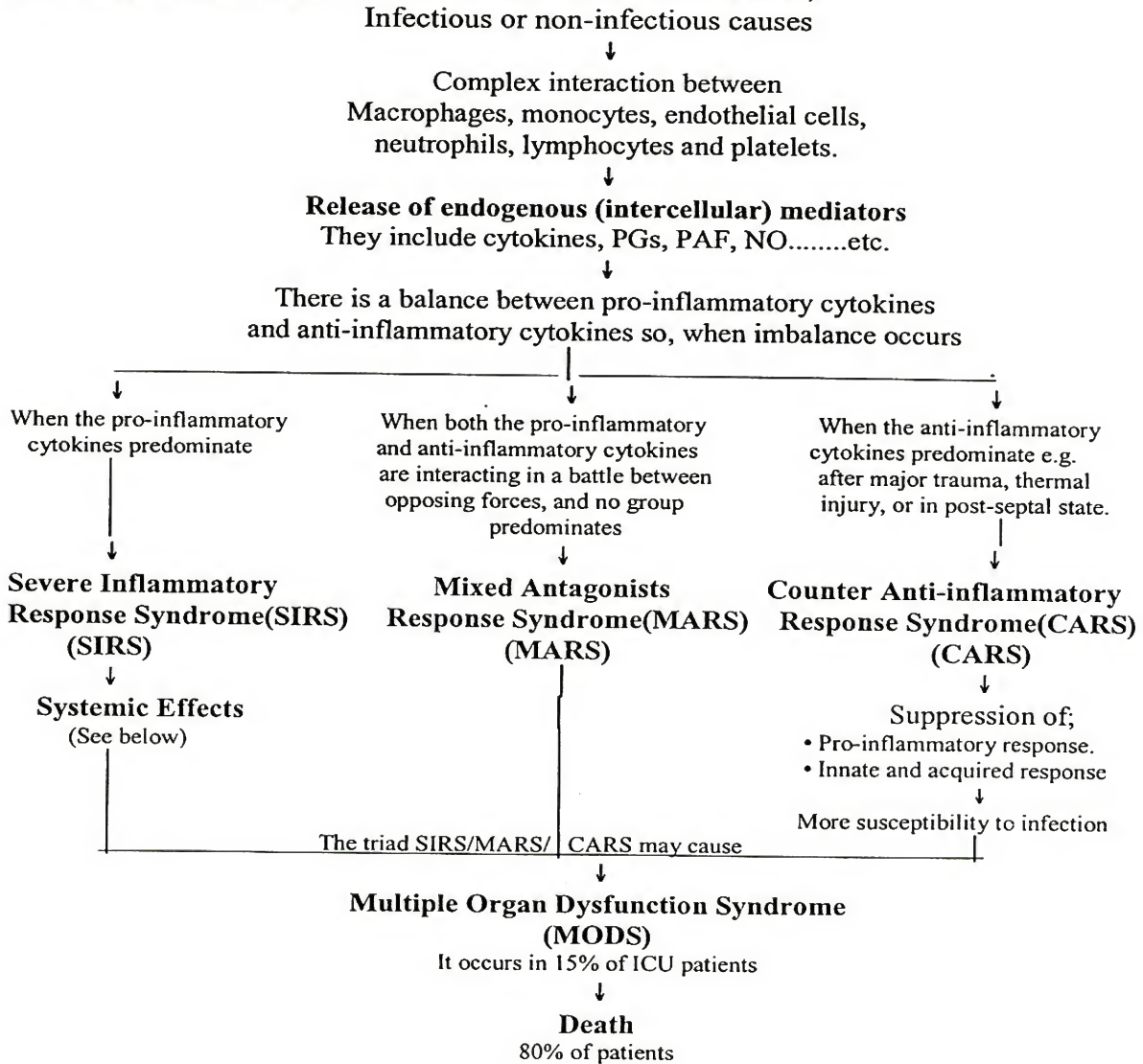
- N.B.; It was previously called Multiple Organ System Failure (MOSF) or Multiple System Organ Failure (MSOF). Both should be avoided, as MODS is now obvious that it is not an all-or-none condition, but rather a continuum of dynamically changing organ failure.

SIRS	- Fever + Leukocytosis
Sepsis	- SIRS + Infection
Severe sepsis	- Sepsis + MODS
Septic shock	- Severe Sepsis + Refractory hypotension

N.B.:**Infection:**

- It is a **microbial phenomenon** characterized by an inflammatory response to the presence of microorganisms or the invasion of normally sterile host tissue by those organisms.
- It may be bacteria (+ve or -ve), fungus, virus, or parasite.
- Site of infection: is usually known, but not always.

Bacteremia: - It is the presence of viable bacteria in the blood.

Pathophysiology: (of SIRS, Septic shock, and MODS)

If the mediators balance each other and the initial response is overcome, **homeostasis** is restored.

Systemic Effects:**1- Coagulation Effects:**

- **Activation of the coagulation cascade (extrinsic pathway)** due to tissue factor production. This causes formation of fibrin-platelet aggregates i.e. **DIC** that causes obstruction of systemic and pulmonary microcirculations.

- **Activation of platelets.**

2- Vascular Effects:

- **Systemic:** - **Increased capillary permeability** causing **hypovolemic shock**.
 - Vasodilatation (arteriolar and venular by NO) that **decreases SVR**, causing **distributive (hyperdynamic) shock**.
 - Leukocyte (especially neutrophils) aggregation and attraction which release proteases and O₂ free radicals causing **damage of the vascular endothelium** that causes **distributive shock** also.

Finally, **irreversible shock** occurs.

- **Pulmonary:** - Pulmonary VC that increases PVR causing **pulmonary hypertension**.
 - Damage of pulmonary endothelium causing **ARDS**.
- **Renal:** - VC of the renal artery, that causes renal hypoperfusion causing **acute renal failure**.
- **Hepatic:** - VC of the hepatic artery that causes hepatic hypoperfusion causing **hepatic dysfunction**. So, liver enzymes are elevated and **septic encephalopathy** (similar to hepatic encephalopathy) occurs.
 - Release of acute phase proteins as C-reactive protein that help in phagocytosis, takes place.

3- Cardiac Effects:

- **Direct myocardial depression** (even with high CO) due to;
 - Presence of myocardial depressant factor (s).
 - Myocardial ischemia.
 - Prolonged CA stimulation, which causes down regulation of β - receptors.
 - Prolonged CA stimulation, which causes myocardial fibers degeneration.
 - Myocardial edema.
 - Increased PVR.

So, **cardiogenic shock** occurs.

- Diastolic hypotension causes **coronary hypoperfusion**.

4- Immune System:

- Stimulation of T and B cells

5- Bone Marrow Effects:

- Increased production of neutrophils and monocytes to help in phagocytosis.

6- Brain Effects:

- Fever (cytokines act on the hypothalamus), anorexia, somnolence, and ACTH secretion.

7- Apoptosis: It is death of the cells after days from the ischemic insult.

Endogenous Mediators:

1- Cytokines:

- They are released from macrophages and monocytes try to the stimulatory effect of endotoxins and exotoxins.
- e.g. interleukin 1, 6, 10, interferons, tumor necrosis factors...etc.

2- Arachidonic Acid Metabolites:

As PGE₁, PGE₂, thromboxane A₂, PGI₂, and Leukotrienes.

3- Platelet Activating Factor (PAF): It is released by endothelial cells.

4- Other Mediators:

- 1- Oxygen free – radicals.
- 2- NO.
- 3- Coagulation factors.
- 4- Complement C5a.

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- 5- Endorphins.
- 6- Myocardial depressant factors.
- 7- Kinins.
- 8- Complement-derived anaphylatoxin.

C/P: (Of SIRS, Septic shock, and MODS)**A) C/P of SIRS:**

.....See the systemic effects.

B) C/P of Septic Shock:

1- C/P of the **source of infection**. It may **coincide** with symptoms and signs of sepsis or it may occur **several hours or days after** recognition of sepsis.

Abrupt onset of fever, chills, nausea (and often vomiting), decreased mental status, and in old debilitated patients and infants, **hypothermia** occurs.

2- The **systemic effects of SIRS** may be present.....etc.

3- CVS: **whether hyper- or hypo-dynamic shock** depends on;

Hyperdynamic shock	Hypo-dynamic (hypovolemic) shock
- It usually occurs early and lasts up to 24 hrs.	- It usually occurs late .
- It occurs in; • Normovolemic patients (usually young and previously healthy patients).	- It occurs in; • Hypovolemic patients as VD and transudation of fluid into tissues occurs. • Preexisting cardiac dysfunction
- CO: Normal or ↑ and PCWP is ↓. - VD (↓ SVR): So, warm & flushed extremities. - Blood volume (CVP): Normal or ↑. - Myocardial depression: Mild. - S_uO₂ ↑ i.e. there is ↓ tissue O ₂ utilization.	- CO: ↓ and PCWP is ↑. - VC (↑ SVR): So, pale, cold, and cyanotic extremities. - Blood volume (CVP): ↓ - Myocardial depression: Severe. - S_uO₂ ↓ i.e. hypoxia.

C) C/P of MODS:

- Typically, the following **sequence of organ failure** occurs. During the **first 3 days** of the original insult, **respiratory failure** commonly occurs. This is followed by **hepatic failure** within **5-7 days**. **GIT bleeding** occurs within **10-15 days** and finally **renal failure** occurs within **11-17 days**, but variable sequences are present. **Mortality** is present in **80%** of cases with MODS.

Investigations: (Of SIRS, Septic shock, and MODS)

1- Assessment of tissue perfusion:

E.g. - ↑ s. lactate levelSee before monitoring of anesthesia.

2- Complete blood picture: shows leukocytosis.

3- Arterial blood gases: show metabolic acidosis and compensatory respiratory alkalosis.

4- Kidney function tests: show increased BUN and s. creatinine.

5- Liver function tests: show increased liver enzymes and bilirubin.

6- Hyperglycemia.

7- Hematology: shows increased FDPs i.e. DIC and thrombocytopenia.

Management: (Of SIRS, Septic shock, and MODS)

Early diagnosis and treatment of infection (before the onset of shock) is the most important prophylactic measure, by early surgical debridement or drainage with appropriate antibiotics.

I) Immediate Resuscitation:

- **A** → Airway up to intubation
- **B** → Breathing up to mechanical ventilation

- C → Circulation (**hemodynamic resuscitation**) which includes;

1- Restoration of Blood Volume;

- Type: - **Colloids are preferred than crystalloids** due to;

- They remain intravascular for longer periods.
- The volume used is 2-3 times less than crystalloid volume.
- They show a decrease in the % of edema formation. Even more, they may decrease edema which may occur in sepsis.
- Hestereil decreases capillary leak.
- Synthetic colloids are relatively inexpensive.
- RBC transfusion must often be added to keep an optimal Hct \approx 30-35%.

N.B.; Hypertonic saline is shown to be useful as;

- It restores hemodynamic parameters.
- It improves macrophages and T cell function, so it increases resistance to infections.

- Volume: It is variable depending on **PA catheter**.

CVP is unreliable because it has little correlation with left side preload.

Therefore: to determine the amount given;

Repeat fluid challenges and repeat hemodynamic evaluation. Once the CO reaches a plateau, discontinue fluid administration.

2- Restoration of Tissue Perfusion Pressure (Inotropes):

- Accepted values: - Systolic BP 90-100 mm Hg.
- MAP 70-75 mm Hg.

Some patients respond to fluid management alone (usually 1-3L) while other patients need vasopressors (beside the fluid) e.g. dopamine, adrenaline, dobutamine, or noradrenaline.

N.B.; Patients with refractory hypotension, and not responding to inotropes, suspect severe acidosis. It should be treated with NaHCO_3 till the pH is increased > 7.2 .

3- Restoration of O₂ Delivery:

- Accepted values: - $\text{SaO}_2 > 95\%$
- $\text{PaO}_2 > 60$ mm Hg.
- Hct $> 30\%$
- By O₂ and inotropes especially dobutamine.

4- Reduction of O₂ Demands:

- By controlling - Body temperature. - Anxiety - Pain
- Type of respiration, as early mechanical ventilation is needed to decrease the work of breathing to decrease O₂ demand.

5- Splanchnic Resuscitation:

- It should be initiated early to prevent or reverse intra-mucosal acidosis.
- Gastric intra-mucosal acidosis is used as a marker of the adequacy of splanchnic perfusion.
- Splanchnic resuscitation is achieved by **adequate and early enteral nutrition**, supplemented especially with **glutamine**, because this maintains the gut mucosal barrier function and decreases bacterial translocation.

II) Control of Infection:

1- Surgical Control:

- Eradication of the cause e.g. - **Drainage of pus** (abscess, empyema, peritonitis).
- **Debridement** of necrotic tissues.
- Other diagnostic studies may be needed e.g. thoracocentesis, paracentesis, lumbar puncture or CT scan.

2- Antibiotics:

- Usually **start with empirical antibiotics** until culture and sensitivity tests results appear.

INTENSIVE CARE**3- Selective Decontamination of the Digestive Tract (SDD):**

- It involves the use of non-absorbable and intravenous antibiotics.
- It prevents bacterial translocation but its role is still controversial.

III) Immunotherapy: (under trials)

- It is **antibodies or soluble receptors directed against bacterial toxins and cytokines** e.g. anti TNF antibodies, soluble TNF receptors, anti-endotoxins antibodies, or soluble complement inhibitors.
- Granulocyte colony stimulating factors or Granulocyte- macrophage colony stimulating factors: They stimulate neutrophilic immunological responses and produce a short period of neutropenia. They prolong the survival time.

N.B Granulocyte transfusion may be used in refractory gram -ve bacteria.

IV) O₂ Free Radical Scavengers (Antioxidants):

- E.g. - N- acetyl cysteine.
- Superoxide dismutase.
 - Vitamin C, E, or selenium.

V) Others:**1- Opioid Peptides: (Naloxone)**

- Action: to counteract the β endorphins mediated VD.

2- Glucose Insulin K⁺ Infusion (GIK):

- Action: +ve inotropic action used in case of low CO unresponsive to vasoactive drugs.

3- Pentoxifylline: (very promising).

- Action: It is a phosphodiesterase inhibitor that increases cAMP so, cytokine-induced leukocyte activation, adherence and degranulation are decreased.

4- Steroids:

- Action:
 - Inhibit phospholipase A₂ that decreases enzymes responsible for arachidonic acid metabolism and PAF production.
 - Inhibit activation of the complement cascade and synthesis of TNF α and IL-1.
 - Reverse adrenal insufficiency associated with advanced sepsis.

VII) Treatment of Complications:

E.g. • DIC by pro-coagulant inhibitors as anti-thrombin III.

- ARDs.....etc.
- **Activated Protein C** produces;
 - Inhibition of coagulation by proteolysis of activated factors Va and VIIIa.
 - Inhibition of production of pro-inflammatory cytokines.

So, activated protein C inhibits both procoagulants and pro-inflammatory pathways.

Nutrient and Energy Requirements

- Energy is normally derived from dietary or endogenous carbohydrates, fats, and proteins. Metabolic breakdown of these substances yields the ATP required for normal cellular function.
- Dietary fats and carbohydrates normally supply most of the body's energy requirements. Dietary proteins provide amino acids for protein synthesis.
- **Neurons, RBCs, and cells of the renal medulla normally utilize only glucose.**
- Excess amino acids can be converted to carbohydrate or fatty acid precursors.
- Excess carbohydrates are stored as glycogen in the liver and skeletal muscle. When glycogen stores are saturated (200-400 gm in adults), excess carbohydrates are converted to fatty acids stored as triglycerides primarily in fat cells.

- Excess fat is stored as triglycerides in fat cells also.

Total Energy Requirement:

It consists of;

1- Basal Metabolic Rate (BMR) or Basal Energy Expenditure (BEE):

- It is the energy expenditure measured in the morning immediately after awakening, 12 hours after the last meal, and in a state of thermal neutrality.
- Clinically BEE in kilocalories is estimated by the **Harris-Benedict Equation**

- Male's BEE = $66 + (13.7 \times \text{body weight in Kg}) + (5 \times \text{Height in cm}) - (6.8 \times \text{Age in years})$.
- Female's BEE = $655 + (9.6 \times \text{body weight in Kg}) + (1.8 \times \text{Height in cm}) - (4.7 \times \text{Age in years})$.

2- Specific Dynamic Action:

- It is the energy required for digestion of food.

3- Person's Activity Level.

Daily Energy Expenditure:

Derived from Harris-Benedict equation;

- **Resting Energy Expenditure (REE) = BEE x 1.2** (thermal effect of food intake).
- It is increased in the following conditions (estimated by multiplying in stress factor)
 - Fever (for each one °C above the normal body temperature): BEE x 1.1
 - Mild stress: BEE x 1.0-1.25
 - Moderate stress: BEE x 1.25-1.5
 - Severe stress: BEE x 1.5-1.75

- Most nutritionists, give critically ill patients only 20-30 Kcal/Kg/day, as such patients have impaired cellular metabolism i.e. glucose and fatty acids are not completely oxidized.

N.B.; In human, Calories units used are always;

Kilocalorie (Kcal) = Big calorie = Calorie 'the C always capital, where the Calorie = 1000 calories.

Component of Daily Energy:

The daily energy requirement should be provided by calories derived from carbohydrates and lipids. Protein intake should be used to maintain the stores of enzymes and should not be included in energy requirement.

I) Carbohydrate Requirements:

- It should supply 70% of non-protein calories.
- Excessive intake leads to;
 - 1- Stimulation of insulin release.
 - 2- The oxidative metabolism of glucose produces increased CO₂ relative to the O₂ consumed i.e. increased carbohydrate, increases CO₂ production causing hypercapnia especially in patients with compromised lung function.

II) Lipid Requirements:

- It should supply 30% of non-protein calories.

III) Protein Requirements:

- Normally, non-stressed persons require; 0.8 – 1.0 g/kg of protein.
- Critically ill patients' with hyper-metabolism require; 1.2 – 1.6 g/kg of protein.
- More accurate assessment of daily protein requirements, requires measuring the urinary excretion of nitrogen.

Nitrogen (N₂) Balance:

- Proteins are composed of 16% nitrogen.
- Each gram of urinary nitrogen represents 6.25 gm protein.
- Or 6.25gm protein give 1 gm of N₂.

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- N_2 Balance (g) = N_2 input – N_2 output.

$$= \text{Protein intake} / 6.25 - (\text{Urinary urea nitrogen in gm/L} \times 1.2 \times \text{Urine volume}) + 2$$

The number 2 represents the daily nitrogen loss, other than urinary urea nitrogen, as fecal losses.

Urinary urea nitrogen (UUN) is multiplied by 1.2 since UUN represents only 80% of urinary nitrogen losses.

- The **aim** of the N_2 balance: is to maintain a **+ve balance of 4-6 gm**.
- **N_2 balance and caloric intake:**
- The 1st step in achieving a +ve N_2 balance is to provide enough non-protein calories to spare protein from being degraded to provide energy.
- If the non-protein caloric intake is insufficient, some proteins in the diet will be broken down to provide energy, producing a -ve N_2 balance.

IV) Vitamin Requirements:

- There are 12 vitamins which are considered essential.
- They include; vitamin A, vitamin B₁, B₂, B₆, B₁₂, vitamin C, D, E, K, Pantothenic acid, Biotin, and Folate.

Anti-oxidant Vitamins includes "Vitamin C and E":

V) Essential Trace Elements:

They are substances that are **present** in the body in an amount **< 50 mg/gm tissue**. They include copper, iodine, chromium, iron, zinc, manganese, and selenium.

Enteral Nutrition

Trophic Effect of Enteral Nutrients:

- Bowel mucosa depends on nutrients in the bowel lumen to provide its nutritional need especially the amino acid **glutamate** which is considered as the principle metabolic fuel for intestinal epithelial cells.
- Complete bowel rest for a few days, causes atrophy and disruption of intestinal mucosa with subsequent **bacterial translocation** i.e. pathogens move across the disrupted mucosa to the systemic circulation.

Indications:

- Any case with inadequate nutrient intake for **> 5 days**.
- In patients at a high risk of bacterial translocation (e.g. burns), tube feeding should be started as early as possible.

Contraindications:

- 1- Circulatory shock.
- 2- Intestinal ischemia.
- 3- Complete mechanical bowel obstruction.
- 4- Ileus.

Total enteral feeding is not advised in:

- Partial mechanical obstruction of the bowel.
- Severe diarrhea.
- Pancreatitis "use jejunostomy feeding".
- High volume (< 500 mL daily) fistulas.

Feeding Formulas:Components of Feeding Formulas:A) Proteins:

- The usual feeding formulas contain **35 – 40 gm protein/L**.

In **protein-rich formulas** (HN = high nitrogen), there is **20% more protein**.

B) Carbohydrates:

- Feeding formulas contain **70% of their total calories** in the form of carbohydrates.
- Each **one gram** carbohydrate gives **3.4 Kcal**.

C) Lipids:

- Feeding formulas contain **30% of their total calories** in the form of lipids.
- Each **one gram** lipid gives **9 Kcal**.
- A **lipid-rich formula**: It is a formula with high lipid content, about **55% of the total calories**. It is used for patients with **respiratory failure** to decrease CO₂ production by carbohydrates.

D) Additives and Special Formulas:

1- Glutamine: It is the principal fuel for bowel mucosa. It maintains the functional integrity of bowel mucosa.

2- Dietary Fibers:

a- **Fermentable Fibers:** As 'cellulose, pectin, and gums'.

- They are degraded by intestinal bacteria producing short chain fatty acids (e.g. acetate). They are used as energy substrates by large bowel mucosa, so they **decrease** the tendency for **translocation** across the large bowel mucosa.
- They decrease gastric emptying and bind bile salts **decreasing diarrhea**.

b- **Non-Fermentable Fibers:** As "lignin"

- They are not degraded by intestinal bacteria.
- They create an **osmotic force** that absorbs water from the bowel lumen, **decreasing** the incidence of **watery diarrhea**.

3- Branched Chain Amino Acids: As "isoleucine, leucine, and valine".

- Formulas containing branched chain amino acids are **used in** patients with **hepatic encephalopathy, hyper-catabolic states and trauma**. They can antagonize the uptake of aromatic amino acids 'tryptophan' into the CNS and prevent its breakdown and formation of false neuro-transmitter, which is one of the theories of pathogenesis of hepatic encephalopathy. In trauma, branched chain amino acids can be used as a fuel source in skeletal muscles, sparing degradation of other muscle proteins to provide energy.

Feeding Regimen:

- Tube feeding is usually infused for **12 – 16 hours/day** starting at a rate of 25 mL/hr and increased slowly over the course of a few days.
- Avoid continuous infusion because it causes stress to the bowel mucosa and promotes malabsorption and diarrhea.
- A **gastric retention test** is done to assess tube feeding where a volume of H₂O equal to the desired hourly feeding volume is infused over 1 hour, then the feeding tube is clamped for 30 min. The tube is unclamped and the residual volume is aspirated.
If the residual volume is < 50%, gastric feeding can be proceeded.
If the residual volume is > 50%, jejunal feeding may be suitable.

Complications:

1) Tube Occlusion:

- **To avoid this problem;** flush the tube with **30 mL water /4 hours** and flush the tube with 10 mL water after medications.

2) Gastric Distension:

- It increases the risk of regurgitation and pulmonary aspiration so, use duodenal or jejunostomy tubes.

INTENSIVE CARE**3) Aspiration:**

- It is **diagnosed** by the presence of **> 20 mg glucose/dL in the tracheal aspirate**, which is detected by glucose reagent strips and an automated glucose meter.
- **To avoid this problem**; elevate the head 45° to decrease the risk of aspiration.

4) Diarrhea:

Causes:

- 1- Hypertonicity of enteral feeding solutions cause osmotic diarrhea.
- 2- Medicinal elixir that contains sorbitol (to improve palatability), which is an osmotic agent.
- 3- Clostridium difficile enterocolitis (secretory diarrhea).

Stool Osmolal Gap

- It is a method to differentiate between secretory diarrhea caused by clostridium difficile enterocolitis and osmotic diarrhea.

- Osmolal gap = Stool osmolality – 2 (stool $[Na^+]$ + stool $[K^+]$)

If the osmolal gap is **> 160 mosm/Kg H₂O**, it is osmotic diarrhea.

If the osmolal gap is **< 160 mosm/Kg H₂O** or –ve gap, it is secretory diarrhea.

Total Parenteral Nutrition (TPN)

It is indicated if the GIT can not be used or if absorption is inadequate.

Intravenous Nutrient Solutions:**Components:****A) Dextrose Solutions:**

- Carbohydrates should provide **70%** of the daily caloric requirements.
- Dextrose solutions must be concentrated to provide enough calories, because dextrose is not a potent metabolic fuel, as **1 gram carbohydrates gives 3.4 Calories**.
- Therefore dextrose solutions used for total parenteral nutrition (TPN) are **hyperosmolar** and should be **infused through a central line**.

Strength	Concentration 'gm/L'	Energy 'Kcal/L'	Osmolarity 'mOsm/L'
5%	50 x 3.4 →	170 x 5 →	250
10%	100	340	505
20%	200	680	1010
25%	250	850	1260

N.B.; 5% means every 100 mL contains 5 grams.

B) Amino Acid Solutions:

- The standard amino acid solution contains 50% essential amino acids.
and 50% non-essential amino acids.
- **One gram protein gives 3.4 Calories**, but this is not calculated as apart of the daily caloric needs.
- The metabolism of essential amino acids, produces a less rise in BUN concentration, so amino acid solutions used in **renal failure are rich in essential amino acids** as phenylalanine and methionine and **low in branched-chain amino acids** as leucine, isoleucine, and valine.
- Nutrition formulas can be supplemented with **branched chain amino acids**, low in aromatic amino acids. These are used in
 - **Hyper-catabolic states "trauma"**.
 - **Hepatic failure**.
- **Glutamine:**
It reduces the atrophic changes in the bowel mucosa during periods of bowel rest.

C) Lipid Emulsions:

- These are long-chain triglycerides rich in linoleic acid.
- **One gram lipid gives 9-10 Calories.**
 - In 10% lipids, the caloric density is 1 kcal/mL.
 - In 20% lipids, the caloric density is 2 kcal / mL.
- Lipid emulsions are **isotonic** to plasma and can be infused through **peripheral veins**.
- Lipids are used to provide **30%** of daily caloric requirements, but they **promote oxidant-induced cell injury** so, **lipid restriction** is indicated in **critically ill patients** who often have high oxidation rates.
- Deficiency of fat intake for one week, produces deficiency in essential fatty acids that causes dermatitis, alopecia, hepatomegaly (fatty liver) and defective immunity.

D) Additives:

- As • Electrolytes (Na, K, Cl, Mg, Ca or P)
 - Vitamins.
 - Trace elements.
- They must be added to TPN. They are added directly to amino acids or dextrose mixtures.

TPN Regimen:**• Step I:**

- Estimate the daily caloric and protein requirements.
- Every **one kg of body weight needs 25 Calories/day.**

and 1.4 gram protein/day.

E.g. 70 kg person, - Calorie requirement = $25 \times 70 = 1750$ kcal/day.
 - Protein requirement = $1.4 \times 70 = 98$ g/day.

• Step II:

Caloric requirements should be = $25 \times 70 = 1750$ kcal/day.

70% carbohydrate

i.e. $1750 \times 70/100 = 1225$ kcal.

1500 mL D_{25%}

As one mL D_{25%} gives 0.85 kcal

So; 1500 mL D_{25%} gives 1275 kcal

30% lipid

i.e. $1750 \times 30/100 = 525$ kcal.

500 mL lipid 10%

one mL lipid 10% gives 1 kcal

So; 500 mL lipid 10% gives 500 kcal

• Step III:

- Protein requirement = $1.4 \times 70 = 98$ g/day.

One liter amino acid 10% i.e. there are 10 grams/100 mL solution i.e. one liter amino acid 10% contains 100 grams.

• Step IV:

Add the standard electrolytes, vitamins, and trace elements.

Therefore, the TPN for a 70 kg body weight person will be;

- D_{25%} → 1500 mL
- Amino acids 10% → 1000 mL
- Lipid 10% → 500 mL
- + Electrolytes, vitamins, and trace elements.

Complications of TPN:**1) Catheter-Related Complications:**

- All **central line complications** can occur because amino acids and D_{25%} are hyperosmolar solutions and need a central line.
- These complications include pneumothorax, hemothorax, air embolism, cardiac tamponade, vein thrombosis as vena caval thrombus, or infection around the catheter. N.B.; The osmolality of infused solutions should be kept < 900 mosm/L to be given in a peripheral cannula e.g. 1.5% amino acids, 10% dextrose or 10% or 20% lipid solutions (lipids are isotonic).

2) Carbohydrate Infusion:

- **Hyperglycemia:** so, insulin must be added to the TPN solution. Insulin is adsorbed to all plastic and glass used in i.v. sets so; a loss of 20-30% should be expected.
- **Hypophosphatemia:** because there is increased uptake of phosphate into the cells associated with glucose entry into the cells.
- **Fatty liver:** when glucose calories are more than the daily caloric requirements, lipogenesis occurs in the liver causing fatty liver and reversible cholestatic jaundice.
- **Hypercapnia:** Excessive carbohydrates cause CO₂ retention especially in patients with respiratory failure due to the high "respiratory quotient" of carbohydrates.

3) Lipid Infusion:

- **Oxidant injury:** Lipid infusion increases the risk of oxidation induced cell injury because lipids contain polyunsaturated fatty acids (the same oxidation-prone lipids in cell membranes).
- **Impaired oxygenation:** Free fatty acids cause damage of the pulmonary capillaries (fat embolism syndrome).

Infusion of oleic acid in animals produces ARDs.

4) GIT Complications:

- **Mucosal atrophy:** complete bowel rest causes atrophy and disruption of bowel mucosa leading to **translocation** that in turn produces septicemia.
- **Acalculous cholecystitis:** Absence of lipids in the proximal small bowel prevents cholecystokinin mediated contraction of the gallbladder with subsequent bile stasis.

5) Metabolic Complications: As;

- Electrolyte and acid base disturbances.
- Vitamin deficiency or excess.
- Trace element deficiency as iron, causing anemia.
- Hypo- or hyperglycemia.

CHAPTER 39

DENTAL ANESTHESIA

General Precautions:

- 1- **General anesthesia** in dental surgery should be **avoided whenever possible**. It should be with the same standards in respect of personnel, and equipment. **Sedation** must be used in preference to general anesthesia wherever possible with training in sedation techniques and on the drugs and techniques to be used.
- 2- All anesthetics should be administered by **an experienced anesthesiologist** and the anesthetic training should include specific experience in dental anesthesia.
- 3- There must be teaching, training, and assessment of **resuscitation skills** and resuscitation further within dental practices.

Type of Anesthesia for Dental Surgery:

- 1- **Outpatient anesthesia** for simple extractions of teeth (mainly in children) (**dental chair anesthesia**).
- 2- **Day-case anesthesia** for straight forward extractions or for minor oral surgery.
- 3- **In-patient anesthesia** for more complicated surgery.

Outpatient Dental Anesthesia (Dental Chair Anesthesia)

The use of GA for outpatient dental surgeries is now decreasing due to:

- 1- General improvement in dental hygiene.
- 2- Increased use of local anesthetics and sedation techniques.

Preparative Management:

1- Equipment:

- The same standard equipment as in inpatient anesthesia; e.g. anesthetic machines, O₂, masks, laryngoscopes, suction, minimal monitors (pulse oximetry, ECG, NIBP, capnography).
- A full range of **resuscitation equipment** must be available.
- **The chair** should be capable of **head down tilt** and should be movable even in the event of power failure.
- An anesthesiologist, dentist, and dental nurse all trained in resuscitation and working as a team.

2- The same precautions of day case anesthesia:

- Surgical case selection.
- Patient selection.
- Patient preparation.

3- Potential preoperative problems:

- A high proportion of the patients are **children** who may have **URTI**.
- Dental abscess may lead to **difficult airway management**.
- The site may have inadequate facilities or equipment.

Intraoperative Management:

Monitoring: Standard.

DENTAL ANESTHESIA**Choice of Anesthesia:****A) Conscious Sedation and Local Analgesia:****Definition:**

A carefully controlled technique in which a **single intravenous drug**, or a combination of oxygen and nitrous oxide is used, to reinforce hypnotic suggestion and reassure in a way which allows:

- Dental treatment to be performed with minimal physiologic stress.
- Verbal contact with the patient, maintained at all times i.e. **conscious sedation**.

The technique must carry a wide margin of safety, enough to render unintended loss of consciousness unlikely.

For the degree of sedation:.....see pediatric anesthesia.

N.B.; Some authors consider that any technique of sedation, other than the one defined above, as coming within the meaning of dental general anesthesia e.g. the use of a benzodiazepine in combination with an opioid for a surgical procedure.

Aim: - The patient feels no anxiety.

- The patient is cooperative although drowsy, but easily arousable.

Technique:**a- Intravenous Sedation:**

- A i.v. cannula is inserted and monitoring with a pulse oximeter is applied.
- **Increments of benzodiazepines**, usually **midazolam**, are given and the amount is titrated according to the patient's response. (midazolam is short acting and has no active metabolites. So it is better than diazepam.

The end point for titration of midazolam or diazepam is:

- The onset of **verrill's sign**, which is drooping of the eyelids (ptosis) (it is considered by some authors to be too deep a level of sedation).
- The patient starts to have a **delayed response to verbal commands**. It is important that verbal contact is not lost at any stage.
- After an appropriate level of sedation is reached, **local analgesia** can be placed in the usual manner and the procedure can be started.

b- Inhalational Sedation (Relative Analgesia):

- It can be used in adults and children, but requires a degree of cooperation from the patient. It is useful in **patients who have needle phobia** from local injection in the mouth.
- By the use of a **low inspired concentration of N₂O in O₂**, by a **nasal mask** which can be clipped around the head. The **initial concentration of N₂O in O₂** used is **5-10%**. **Then increase the concentration in 5% increments up to 30%.**

The use of a higher concentration of N₂O may cause restlessness and occasionally aggression of the patient. Also, the operator should maintain a verbal contact with the patient.

Advantages (over i.v. technique):

- Recovery is more rapid.
- The patient is ready for early discharge and there is less restriction on mobility within the first 24 hrs.

Relative contraindication (over i.v. technique):

- 1- A blocked nose.
- 2- Deafness.
- 3- Uncooperative patients due to physical or mental disability.
- 4- Active neurologic disease.
- 5- Severe respiratory disease.

B) General Anesthesia:

GA is indicated in outpatients especially in cases of;

1- **Ineffective local analgesia.**

2- **Uncooperative patients** due to mental impairment or physical disability.

3- **Patient's refusal of local analgesia and sedation** (but it should be discouraged).

Induction and Airway Management: The same as day case anesthesia with the following precautions:

- A **nasal mask** is used.
- A **gag or bite block** is applied by the dentist or the anesthesiologist. It should **not** be too large in size to avoid over opening of the jaw as this may make the airway more difficult to be maintained.
- A **mouth pack** is placed to prevent debris from extracted teeth falling into the airway. It should **not** be placed too far posteriorly **in the mouth** so as not to compromise the nasal airway.
- As the airway is shared by the dentist and anesthesiologist, so at any time throughout the procedure, if there is a problem with the airway, it is important that the anesthesiologist interrupts the surgery until the airway is restored.

Maintenance: The same as day case anesthesia with the following precautions:

It is done by either;

a- Volatile agents with spontaneous ventilation using the nasal mask with O₂ and N₂O.

b- Propofol, either i.v. infusion or incremental boluses.

Recovery: See later.

Postoperative Management:

See later for postoperative problems.

Day Case Anesthesia

Day-case anesthesia differs from the outpatient dental chair anesthesia in that the patient goes through a **formal admission to the hospital**, but is **discharged home later in the day**.

Preoperative Management:

See before, day case anesthesia.....

Intraoperative Management:

Monitoring: Standard

Choice of Anesthesia:

Induction and Airway Management: The same as day case anesthesia with the following precautions;

- **Naso-tracheal intubation** is used (oro-tracheal intubation can be used although not ideal. It is used if there is difficulty in nasal intubation e.g. deviated septum)
- A **gag or bite block** is applied by the dentist or the anesthesiologist.
- A **throat pack** should be placed by the anesthesiologist in the back of the mouth, around the endotracheal tube to prevent any blood or debris falling into the back of the larynx. The tail of the throat pack should be brought out of the mouth and secured to make sure that it is removed at the end of surgery.

Maintenance:

The same as day case anesthesia.

Recovery and Extubation:

- 1- At the end of the procedure, the **oral or throat packs and gags are removed** and other **packs are usually placed across the sockets of the teeth** to absorb any continuing bleeding.

DENTAL ANESTHESIA

- 2- **Awake extubation** should be done in the **left lateral, head down position** then the patient is allowed to **recover in the half lateral position** with 100% O₂, due to the potential for blood and secretions to pass down the larynx.
- 3- **A nurse** should be there to supervise the recovery.

Postoperative Management:**Postoperative Complications:****a- Immediate:**

- 1- **Hypoxemia** secondary to diffusion hypoxia or airway problems.
- 2- **Airway problems** caused by laryngeal spasm, bleeding or debris in the airway.
- 3- **Vomiting.**

b- Long Term:

- 1- Continued bleeding.
- 2- Postoperative pain.
- 3- Nausea and vomiting.
- 4- **Postoperative edema:** Some dentists give dexamethazone.

Postoperative Analgesia:

- The amount of pain experienced postoperatively varies with the number of teeth extracted and the difficulty encountered in extraction.
- By:
 - **NSAIDs orally:** It is ideally for postoperative dental pain as some of the pain comes from the tissue swelling. These agents act in a part by decreasing the swelling.
 - **Paracetamol suppositories** (while the patient is anesthetized): It is vital to discuss to use of analgesic suppositions with the patient or the patient's parents preoperatively.

Discharge Criteria: See before criteria for home readiness in day case anesthesia.

In-patient Dental Anesthesia

Indications: E.g.

- 1- Impacted wisdom teeth where considerable surgery is anticipated.
- 2- Extraction of 4 wisdom teeth together.
- 3- Oral surgery on gums and jaw.

Anesthetic Problems:

The same anesthetic problems as above e.g. difficult intubation, throat pack, swelling, and pain. Some surgeons use **laser (with its precautions)**.

CHAPTER 40

ANESTHESIA WITH SKIN & MUSCULO-SKELETAL DISEASES

Scleroderma (Progressive Systemic Sclerosis)

- There is progressive fibrosis (sclerosis) of blood vessels all over the body and skin, of an unknown cause, resulting in multi-system affection.

Anesthetic Problems:

1- Fibrosis of the Skin:

- Limited mobility of **joints** (especially the mandible).
- Narrowing of the **oral opening**.

Both may cause **difficult intubation**.

- Dermal thickening, that may cause **difficult i.v. cannulation**.

2- Fibrosis of peripheral and cranial **nerves** causing **neuropathy**.

3- Fibrosis of the C.V.S. (heart and blood vessels):

- Fibrosis of the **cardiac muscle**, resulting in pericarditis, pericardial effusion, and myocardial weakness up to CHF (with fibrosis of the coronaries).
- Fibrosis of the **conduction system** resulting in arrhythmias and conduction abnormalities.
- Fibrosis of **pulmonary vessels** causing pulmonary hypertension and cor pulmonale.
- Fibrosis of **systemic vessels** causing systemic hypertension.
- Fibrosis of **peripheral vessels** causing Raynaud's disease.

4- Fibrosis of the **lungs** causing diffuse interstitial pulmonary fibrosis (restrictive diseases).

5- Fibrosis of **renal vessels** causing irreversible renal failure.

6- Fibrosis of the **GIT**:

- It decreases the motility of the **lower esophagus** (and decreases the tone of the lower esophageal sphincter) increasing the risk of regurgitation.
- It decreases the motility of the **intestine** resulting in intestinal pseudo-obstruction.

7- It is treated by steroids so a **steroid cover** is needed.

Rheumatoid Arthritis

Causes:

It is an antigen antibody reaction resulting in a chronic inflammatory disease that causes multi-system affection.

Anesthetic Problems:

1- Joints:

- **Temporo-mandibular joint**: there is limited mandibular movement resulting in **difficult intubation**.
- **Cervical spine**: there is atlanto-axial sub-laxation that may cause **dangerous intubation**, as neck extension causes pressure on the spinal cord.
- **Crico-arytenoid joint**: there is hoarseness and swelling in the neck, **needing intubation**. So, a preoperative neck x-ray and precautions for difficult intubation are done.

ANESTHESIA WITH SKIN AND MUSCULOSKELETAL DISEASES

- **Other joints:** they should be checked for the range of movement especially those involved in **patient's positioning**.
- 2- **Skin:** Thin and atrophic (by the disease process and immuno-suppressive drugs resulting in **difficult i.v. cannulation**).
- 3- **CNS:**
 - Psychologic changes and mood changes.
 - Vasculitis resulting in **cerebro-vascular stroke**.
 - **Peripheral neuropathy**.
- 4- **CVS:**
 - Pericarditis, myocarditis, and endocarditis resulting in **arrhythmias, conduction defects, CHF**, affection of the **aortic and mitral valve** (MR and AR).
 - Coronary vasculitis resulting in **ischemia**.
- 5- **Lung:** • **Diffuse pulmonary fibrosis** resulting in **restrictive lung disease**.
- 6- **Kidney:** • **Glomerulonephritis** that causes proteinuria that in turn causes **hypo-albuminemia and renal failure**.
- 7- **Liver:** • **Lupoid hepatitis** with increased liver enzymes up to severe fatal hepatitis.
- 8- **Blood:** • **Anemia, thrombocytopenia**, and leucopenia.
- 9- **Muscle:** **Myopathy**.

Treatment:

- Steroids: - Their complications and steroid covers.
 - NSAIDs: - Their complications
 - Immuno-suppressive drugs: - Their complications.
- All should be assessed.

Marfan Syndrome

It is a connective tissue disease of autosomal dominant inheritance.

Anesthetic Problems:

- 1- Long thin extremities with sub-laxation of the joints may cause **dislocation during positioning**.
- 2- Hyper-extensibility of joints may cause **temporo-mandibular dislocation** during laryngoscopy.
- 3- High arched palate causing **difficult intubation**.
- 4- Lens sub-laxation and retinal detachment may occur.
- 5- **Aortic and mitral regurgitation** and **subacute bacterial endocarditis** so, an antibiotic cover is needed.
- 6- **Ascending aortic aneurysm**.
- 7- Heart: **Conduction system abnormalities**.
- 8- Lung:
 - Kyphoscoliosis causing **restrictive lung disease**.
 - Emphysema causing **spontaneous pneumothorax**.

Kyphoscoliosis (Scoliosis):

Definition:

Deformity of the vertebral column occurs due to;

- Increased anterior flexion (**kyphosis**).
- Increased posterior flexion (**lordosis**).
- A lateral curvature (**scoliosis**).

N.B.: Normally, there is thoracic kyphosis and lumbar lordosis (no scoliosis).

Etiology (and Types):

1- Idiopathic: It is the commonest cause (70-80%). It may be genetic.

- Infantile.
- Juvenile.
- Adolescent.

2- Neuro-muscular (Paralytic):

a- Neuropathic:

- Upper motor neuron (e.g. cerebral palsy or spinal cord injury).
- Lower motor neuron (e.g. poliomyelitis or meningo-myelocoele).

b- Myopathic:

- Muscular dystrophy.
- Myotonic dystrophy.

3- Congenital:

- Hemi-vertebrae.
- Congenitally fused ribs.

4- Neurofibromatosis.

5-Mesenchymal Disorders.

- Marfan's syndrome.

6- Trauma:

- Post-thoraco-plasty.
- Post-radiation.

Effects of Scoliosis:**1- Pulmonary Effects:****a- Restrictive Pulmonary Diseases:**

- There are abnormal pulmonary function tests due to a marked decrease in the chest compliance rather than lung or respiratory muscle affection except in **congenital and infantile scoliosis** in which growth of the lungs may be impaired due to early thoracic deformity.

- See pulmonary function tests:..... Anesthesia with respiratory diseases.

b- Hypoxia and Hypercarbia:**Mild Scoliosis:**

- There is **arterial hypoxemia** (but normal PaCO₂ and pH) due to;
- Ventilation – perfusion abnormalities (the most important cause).

Severe (or Prolonged) Scoliosis:

- There is a more worse **arterial hypoxemia with CO₂ retention and acidosis** (i.e. there is alveolar hypoventilation).

c- Respiratory Failure:

- It occurs in severe untreated scoliosis.
- The risk is increased if the VC is < 50% of the predicted and Cobb's angle is > 100 degrees.

2- CVS Effects:

a- Increased PVR: So, Pulmonary hypertension may occur leading to RV failure.

Due to:

- Hypoxemia that causes pulmonary VC (at 1st reversible but later irreversible changes occur).
- Chest wall deformity that compresses some lung parts increasing the PVR.
- Scoliosis which if present in the 1st 6-8 years of life, impairment of growth of the pulmonary vascular bed occurs.

b- Mitral Valve Prolapse: (The most common heart abnormalities).

It needs prophylactic antibiotics.

c- Associated Conditions with Scoliosis and Affecting the CVS:

ANESTHESIA WITH SKIN AND MUSCULOSKELETAL DISEASES

- Duchenne's muscular dystrophy causing cardiomyopathy.
- Marfan's syndrome (as above).
- Congenital heart diseases: No specific lesion, but scoliosis is more common with cyanotic congenital heart diseases.

3- Malignant Hyperthermia:

- There is an increased incidence (association) of malignant hyperthermia with scoliosis.

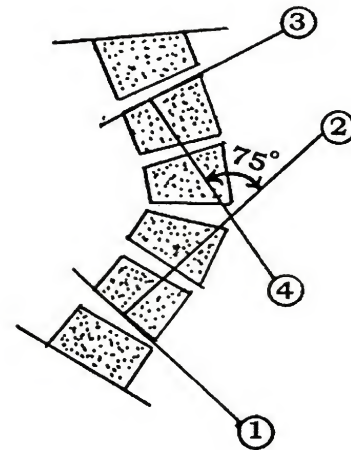
Anesthetic Management:

Preoperative Management:

1- Preoperative Assessment of Scoliosis: (by history, examination, and investigations).

• Severity: by Cobb's angle.

- It was suggested in 1966 by the Scoliosis Research Society (figure 40-1).
- A perpendicular line (2) is constructed from the bottom of the lowest vertebrae (1), the bottom of which tilts towards the concavity of the curve, and another perpendicular line (4) from the top of the highest vertebrae (3) the top of which tilts towards the concavity, is constructed. The angle (5) at which these perpendiculars intersect is Cobb's angle.



- Significance:

- The more severe the thoracic curve (i.e. the greater the Cobb's angle), the more profound the disturbance in pulmonary function.

Curves > **45 to 50 degrees** usually need surgical correction.

Curves > **60 degrees** are usually associated with decreased pulmonary function.

Curves > **100 degrees** are usually associated with severe gas exchange impairment (respiratory failure).

Figure 40-1; Cobb's angle

• Location of Scoliosis:

- In cervical vertebrae, it may cause difficult airway management.
- In thoracic vertebrae, it may be associated with pulmonary function impairment.
- More spread of scoliosis causes more affection.

• Onset of Scoliosis:

- If earlier less than 6-8 years of age, lung development is decreased, as the number of alveoli increase from 20 million at birth to 250 million at 4 years, and continue to develop up to 8 years of age.

• Direction of Scoliosis:

- Most curves in adolescent idiopathic scoliosis are convex to the right, just as most people are right-handed. So, a left convex scoliosis draws attention to search for an underlying disease.

• Causes and Associated Diseases: As above.

• Effects: As above especially cardiopulmonary reserve.

2- Preoperative Neurologic Assessment:

- **To document** preoperative neurologic function to avoid confusion with postoperative neurologic complications.

3- Preoperative Investigations:.....

4- Preoperative Patient Preparation: See anesthesia of spinal surgery.

5- Premedications:

Intraoperative Management:

Monitoring:

Inductions and Intubation:

Position:

Maintenance:

Intraoperative complications:.....

1- If abnormal SSEPs are found:.....

2- Intraoperative Wake up Test:..... See anesthesia of spinal surgery

3- Excessive Blood Loss:..... "Anesthesia for neurosurgery"

Emergence and Extubation:.....

Postoperative Management:

1- Postoperative Ventilation:

2- Postoperative Respiratory Care:

3- Postoperative Analgesia.....

4- Postoperative Complications:.....

Muscle DiseasesSee before.

Anesthesia for Dwarfism

Definition:

- Midgets: It is a proportional short stature.
- Dwarf: It is a disproportional short stature.

Causes:

- 1- Muco-polysaccharidosis.
- 2- Achondroplasia.
- 3- Osteogenesis Imperfecta.

Anesthetic Problems:

A) Airway Problems:

1- Airway and facial anomalies:

- They cause airway obstruction and difficult intubation due to;
- A large tongue, large tonsils and adenoids, thickened nasal, pharyngeal, laryngeal, tracheal and bronchial passages, due to deposition of glycos-aminoglycans.
- Stiff temporo-mandibular joints.
- Short neck.
- Hypoplastic mandible, micro-gnathia, cleft lip and palate.

2- Sleep apnea.

3- Atlanto-axial instability and sub-laxation so, take care during laryngoscopy.

B) CNS Problems:

1- Increased ICT.

2- Increased incidence of macrocephaly and hydrocephalus.

3- Neurologic deficits so, take care with regional anesthesia.

4- Spinal stenosis causing;

- Cauda equina syndrome.
- Muscle weakness.
- Autonomic hyper-reflexia due to injury of the spinal cord above T₆.

ANESTHESIA WITH SKIN AND MUSCULOSKELETAL DISEASES

C) Respiratory System Problems:

- 1- Restrictive lung diseases: Due to • Kyphoscoliosis.
• Chest deformities.
- 2- Obstructive lung diseases: Due to • Tracheo-bronchial narrowing due to deposition of glycos-aminoglycans.

D) CVS Problems:

- 1- Congenital heart diseases as VSD, ASD, and PDA.
- 2- Valvular heart diseases as MV prolapse.
- 3- Cardiomyopathy due to deposition of glycos-aminoglycans in the myocardium.
- 4- Coronary heart diseases due to deposition of glycos-aminoglycans in the coronaries.

E) Metabolic Problems: Increased incidence of;

- 1- Porphyria.
- 2- Malignant hyperthermia.
- 3- Hyper-metabolic states, especially in osteogenesis imperfecta, with increased body temperature and O₂ consumption.

F) Hematologic Problems:

Bleeding tendency due to platelet dysfunction.

G) Renal and Liver Impairment.

H) Psychologic Disorders:

The anesthesiologist must avoid infantilization of the patient.

Porphyria

It is inherited autosomal dominant disorder of porphyrin metabolism characterized by increased activity of **D-amino laevulinic acid synthetase** (DALA synthetase) with excessive production of porphyrin or its precursors.

Acute Intermittent Porphyria:

- C/P:

It is characterized by **acute attacks** which occur **spontaneously** or **are precipitated** by infection, starvation, pregnancy, and drugs (see later).

- 1- GIT: Abdominal pain, vomiting, constipation or diarrhea.
- 2- CNS: • Motor and sensory peripheral neuropathy (It may affect bulbar or respiratory muscles).
• Epileptic fits.
- 3- C.V.S: Hypertension or hypotension and tachycardia.
- 4- Fever and leukocytosis.

Anesthetic Management.

Aim: Avoid precipitating factors and drugs.

Induction: Ketamine or propofol .

Then suxamethonium and vecuronium.

Maintenance: O₂: N₂O + halothane + morphine or fentanyl+ controlled ventilation.

If fits occur, - An anticonvulsant as diazepam is given.

- A sedative as chlorpromazine is given.

Drugs

	Safely used drugs	Drugs used with care as no data is present	Unsafe drugs, which should be avoided
1- I.v. agents	Propofol	Ketamine	Barbiturate, Etomidate
2- Inhalational agents	N ₂ O, Cyclopropane, Diethyl ether	Halothane, Isoflurane	Enflurane
3- Muscle relaxants	Curare, Vecuronium, Suxamethonium,	Atracurium, Pancuronium.	Alcuronium

4- Neuromuscular blockade reversal	Atropine, Neostigmine	Glycopyrrolate	
5- Local anesthetics	Procaine, Amethocaine	Lignocaine, Bupivacaine, Prilocaine.	Mepivacaine
6- Analgesics	Morphine, Pethidine, Fentanyl, Paracetamol Buprenorphine, Naloxone	Alfentanil, Sufentanil	Pentazocine
7- Anxiolytics	Temazepam, Midazolam, Lorazepam, Droperidol, Phenothiazines.	Diazepam, Triazolam, Oxazepam	Other benzodiazepines
8- Anti-arrhythmics	Procainamide, β Blocker	Lignocaine, Mexiletine, Bretyllium, Disopyramide.	Verapamil, phenytoin, Nifedipine, Diltiazem
9- Other C.V.S drugs	Adrenaline, Phentolamine	β agonist, α agonist, Na nitroprusside	Hydralazine, Phenoxylbenzamine
10- Bronchodilators.	Corticosteroids, Salbutamol	Hexaprenaline	Aminophylline
11- Gastric drugs	Metoclopramide, Domperidone	Ranitidine	Cimetidine

CHAPTER 41

ANESTHESIA WITH NEUROLOGIC & PSYCHIATRIC DISEASES

Degenerative and Demyelinating Diseases

1) Parkinson's Disease:

Cause: There is decreased dopamine and increased Ach levels.

Treatment: Anti-parkinsonian drugs as;

- 1- Anticholinergic drugs e.g. benztropine.
- 2- Levo-dopa: it a dopamine precursor.

Anesthetic Problems:

1- **Anti-parkinson therapy** should be **continued perioperatively** even on the morning of the surgery, because the $t_{1/2}$ of levo-dopa is short although most of these drugs are taken orally. The **abrupt withdrawal of levo-dopa** may worsen **muscle rigidity** and **interfere with ventilation**.

2- **Avoid anti-dopaminergic drugs** as phenothiazines, butyrophenones (droperidol), and metoclopramide as **they exacerbate symptoms**.

3- Premedication with **anticholinergics (atropine)** or **anti-histaminics (diphenhydramine)** is beneficial.

4- Observe for **side effects** of drugs especially **levo-dopa** on;

- The CNS: Agitation, irritability, and confusion.
- The CVS: Postural hypotension and tachyarrhythmias
- The GIT: Nausea and vomiting.

so; • Marked hypotension or hypertension can occur on induction of anesthesia necessary ABP monitoring (severe hypotension is treated by direct acting vasopressors as phenylephrine. Due to presence of catecholamine depletion, indirect acting drugs are not effective).

- Arrhythmias can occur especially with halothane, ketamine epinephrine containing local anesthetics so, use them cautiously.

5- **Fentanyl and sufentanil (and other opioids)** induced **muscle rigidity** is exaggerated in parkinsonism patients. This can be treated by neuromuscular blockade.

6- **Inhalational agents:**

- Increase brain extracellular dopamine concentration by decreasing neuronal uptake.
- Decrease dopamine transmission due to blocking of dopamine receptors and decrease neuronal release. So, they produce an unpredictable C/P.

7- Rarely **hyperkalemia** occurs **after succinylcholine** so, it is used cautiously or avoided. But there is a normal response to non-depolarizing muscle relaxants.

2) Alzheimer's Disease:

Definition, cause, and pathology.....See anesthesia for geriatric patients.

Anesthetic Problems:

- 1- Patients are usually **uncooperative and disoriented** so;
 - Repeated **reassurance** and **explanation** are needed.
 - **Consent** should be obtained from a **legal guardian**.
 - Regional anesthesia is not suitable.
- 2- **Physostigmine** (anticholinestrase used in treatment) can **interact with muscle relaxants**.
- 3- When anticholinergics are needed, use glycopyrrolate as it does not cross the BBB. Avoid atropine and scopolamine as theoretically they produce postoperative confusion and exacerbate the C/P, because they cross the BBB.

3) Guillian - Barré Syndrome:

(Acute Demyelinating Polyneuropathy)

Cause and Pathology:

- An **immunologic reaction** against the **myelin sheath** of peripheral nerves especially **lower motor neurons**, usually following **viral infections** as;
 - Respiratory viral infections.
 - GIT viral infections.
 - HIV (AIDs) virus.
- It may occur as a **para-neoplastic syndrome** associated with Hodgkin's disease

Anesthetic Problems:

There is sudden onset of the C/P.

1- Motor Affection:

- **Muscle weakness, atrophy, and spasticity** (treated by diazepam, dantrolene, and baclofen). So;
 - **Avoid suxamethonium** as it may produce hyperkalemia.
 - **Care is taken with non-depolarizing muscle relaxants**
- **Bulbar muscle weakness**, so care is taken to **avoid** the risk of **aspiration**.
- **Respiratory muscle weakness** so, care is taken to assess the **adequacy of ventilation** and the need for **postoperative mechanical ventilation**.

2- Sensory Affection:

- Visual disturbances.
- Paresthesia, and painful dysesthesia (treated by carbamazepine and phenytoin).

3- Autonomic Affection:

Autonomic dysfunction (dys-autonomia) occurs so, care is taken in assessment of the CVS, body temperature, urine retention.....see pediatric autonomic dysfunction.

Psychiatric Disorders

1) Depression:

Cause: Multi-factorial due to brain deficiency of dopamine, norepinephrine, and serotonin.

Treatment: Anti-depressant drugs.

Anesthetic Problems:

a) Tricyclic Antidepressants: e.g. amitriptyline, desipramine, imipramine.

- They block the reuptake of norepinephrine and serotonin or dopamine at the pre-synaptic nerve endings.

ANESTHESIA WITH NEUROLOGIC AND PSYCHIATRIC DISEASES

1. They should be **continued perioperatively**.
 - 2- Their **side effects** should be assessed and managed, as;
 - CNS: Sedation, tremors, confusion, and convulsion.
 - CVS: Postural hypotension and tachyarrhythmias.
 - Liver: dysfunction and jaundice.
 - blood: agranulocytosis.
 - Anticholinergic action.
 - 3- Their **drug interaction** with other drugs.....see the practice conduct of anesthesia.
- b) Mono-Amino Oxidase Inhibitors (MAOIs):** e.g. Phenlazine, tranlycypromine, iproniazide, isocarboxazide
- MAOIs (especially type A) irreversibly inhibit mono-amino oxidase type A. Therefore, they prevent deamination of tyramine, serotonin, norepinephrine, and dopamine.
- 1- They should be **stopped for 2-3 weeks preoperatively**.
 - 2- Their **side effects** should be assessed and managed as; Nearly the same side effects of tricyclic antidepressant drugs.
 - 3- Their **drug interaction** with other drugs.....see the practice conduct of anesthesia.

2) Schizophrenia:

Causes: Increased dopamine activity in the brain.

Treatment: Antipsychotic (neuroleptic, major tranquilizers) drugs. They include;

- Chlorpromazine and promazine.
- Butyrophenones as haloperidol and droperidol.
- Clozapine.
- Sulpride.

Anesthetic Problems.

- 1- They are **continued perioperatively**.
- 2- **Side effects** of antipsychotic drugs should be assessed and managed as;
 - CNS, CVS, liver, blood, and anticholinergic side effects as tricyclic antidepressants.
 - Malignant neuroleptic syndrome.
 - Parkinsonian syndrome.
- 3- Their **drug interaction** with other agents;
 - With anesthetic drugs; **anesthetic requirements** should be **decreased**.
 - With **epileptogenic drugs** as enflurane or ketamine; seizure threshold is decreased so, they should be **avoided**.

N.B.;

Neuroleptosis:

- It is a drug-induced state due to block of dopamine receptors, there is;
- Suppressed spontaneous movements.
- Lack of initiative, disinterest in the environment and a placid appearance.
- Little display of emotions.

But with; • Unpleasant sensations.

- Intact spinal and central reflexes.
- Intact intellectual functions.

Neurolept-analgesia:

- It is neuroleptosis + analgesia without loss of consciousness.
- It is induced by a neuroleptic agent as droperidol and a potent analgesic agent as fentanyl.
- Uses: Sedation during; • Minor surgical procedures.
 - Regional anesthesia e.g. ophthalmic surgery.

- In large doses, profound respiratory depression without loss of consciousness occurs i.e. the patient becomes hypoxic and cyanotic, but remains conscious and responds to orders to breathe, as Ondine's curse.

Neurolept-anesthesia:

- It is neurolept-analgesia (in large doses) + N₂O (that cause loss of consciousness). It is similar to the dissociative anesthesia of ketamine.
- Uses: Induction of anesthesia in;
 - Cardiac surgery.
 - Neurosurgery.

Spinal Cord Injury

.....See anesthesia for neurologic diseases.

Anesthesia & Substances (Drug) Addiction

Definition:

Addiction:

- It is a maladaptive pattern of substance use, leading to clinically significant impairment or distress, as manifested by **three (or more) of the following**, occurring at any time in the same 12-month period;

- **Tolerance** which is defined as either of the following;
 - A need for **markedly increasing amounts of the substance** to achieve intoxication or the desired effect.

Or - **Markedly diminished effect** with continuous use of the **same amount** of the substance.

- **Withdrawal** which is as manifested by either of the following;
 - The characteristic withdrawal syndrome for the substance.
 - The same or a closely related substance is taken to relieve or avoid withdrawal
- The substance is often **taken in larger amounts, or over a longer period** than was intended.
- There is a **persistent desire or an unsuccessful effort** to cut down or **control substance use**.
- A **great deal of time** is spent in **activities necessary to obtain the substance** (e.g. visiting multiple doctors or driving long distances), use the substance or recover from its effects.
- Important **social, occupational, or recreational activities** are given up or **reduced** because of substance use.
- The substance use is continued, despite the fact that a persistent physical or psychological problem is likely to have been caused or exacerbated by the substance.

Other Definition of Addiction:

There is a **continuous need** for the substance, with a **compulsive drug use**, that is accompanied with **tolerance, psychologic and antisocial behavior**, and **physical dependence**.

Physical Dependence:

It is a state that develops as a result of the **adaptation** produced by **resetting of the homeostatic mechanisms** in response to repeated drug use.

N.B.: Differences between addiction and physical dependence:

- **Physical dependence** is manifested by the **presence of a withdrawal syndrome** on abrupt discontinuation of the drug, but the patient may be an addict or not.
- Physically dependent patients follow the prescription of physicians and signs of narcotic maintenance appears, but;

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- They do not go to more than one physician, but addicted patients do, seeking pain medications.
- They do not use illicit substances, but addicted patients do.
- They do not self-escalate the dose, but addicted patients, do without discussing the changes with physicians.
- They do not ask for early refills, but addicted patients do.

Cross-tolerance:

Repeated use of **drugs in one category**, confer **tolerance**, not only to that drug but also to **other drugs in the same structural and mechanistic category**.

Detoxifications:

It is removal of the toxifying drug by either slow tapering or rapid withdrawal.

Relapse:

It is restarting the self-administration, of a drug of abuse, after a period of sobriety.

Sobriety:

It is the complete absence of a drug abuse.

Substance or Drug Abuse:

It is the continuous and repeated use of a drug despite its negative, adverse medical and social consequences.

Withdrawal Syndrome:

It is the development of a pattern of signs and symptoms in response to abrupt removal of the drug of dependence, and central nervous system hyper-arousal due to re-adaptation to the absence of the drug.

The Most Common Drugs and Substance Abused:**A) Cocaine Abuse:**

- It is an alkaloid derived from the leaves of the South American shrub *Erythroxylon coca*.

C/P of Chronic Abuse:**1) CVS: (+)**

1. Myocardial ischemia/infarction (even in the young) due to unclear mechanisms, but may be due to:
 - Increased myocardial O₂ demand.
 - Accelerated atherosclerosis.
 - Coronary VC and spasm.
 - Abnormally increased platelet aggregation by increasing thromboxane production causing cocaine-induced thrombocytopenia.
2. Hypertension.
3. Arrhythmias.
4. LV hypertrophy and cardiomyopathy.

2) CNS: (+)

1. Seizures
2. Cerebral infarctions.
3. Hemorrhagic strokes due to;
 - Rupture of a coexisting aneurysm.
 - Spontaneous bleeding due to sudden increased ABP.
4. Subarachnoid hemorrhage.

3) Obstetric: (+)

1. Pre-term labor.
2. Premature rupture of membranes.
3. Precipitate labor.
4. Abruptio placenta due to maternal hypertension.
5. Spontaneous abortion.
6. Pregnancy induced hypertension.

4) Neonatal:

1. Prematurity.
2. Congenital anomalies.
3. Neurobehavioral abnormalities.
4. Necrotizing enterocolitis.
5. Sudden infant death syndrome.

5) Pulmonary:

1. Cocaine-induced asthma.
2. Hypersensitivity pneumonitis.
3. Chronic cough.
4. Pulmonary edema, due to unclear mechanisms but may be due to;
 - Transient LV dysfunction.
 - Altered pulmonary capillary permeability.
5. Pneumothorax due to barotrauma caused by frequent Valsalva maneuvers done by smokers.
6. Pulmonary hemorrhage.

6) GIT:

- 1- Colitis.
- 2- Intestinal ischemia causing pseudo-obstruction.

7) Addiction Signs:

- 1- Ulceration of the nasal mucosa.
- 2- All extremities show sclerosis of peripheral veins, and needle marks from i.v. injections. These produce;
 - Difficult cannulation.
 - Increased incidence of skin infections.
 - Increased incidence of thrombo-phlebitis.
 - Increased incidence of HIV and hepatitis.
 - Multiple ecchymosis, if there are recent injections.

C/P of Acute Intoxications:

- **Severe sympathetic actions** due to the release and inhibition of the reuptake of CAs. The above C/P, but in a severe form e.g. severe hypertension, arrhythmias, infarction, convulsions.... so, **preoperative propranolol, esmolol, labetalol, hydralazine, or nitroglycerine** are needed.

C/P of Withdrawal Syndrome:

- Psychomotor agitation and insomnia.
- Severe depression and anorexia.
- Autonomic hyperactivity.

B) Opioid (Narcotic) Abuse:

- **Heroin (Di-acetyl morphine)** is produced from morphine, is 3 times more potent and has higher lipid solubility, so it easily crosses the BBB.
- Other opioids can be used e.g. morphine, pethidine and fentanyl. Addicted patients are usually from the medical field especially, anesthesiologists.

C/P of Chronic Abuse:

- 1) Malnutrition and chronic anemia.
- 2) CVS: septic **phlebitis**, bacterial **endocarditis** (tricuspid valve).
- 3) CNS: **Transverse myelitis**.
- 4) Pulmonary:
 - Pulmonary and systemic emboli and infarctions.
 - Pulmonary edema and anaphylactic reactions.
 - **Aspiration pneumonitis**.
 - Atelectasis. • Bronchospasm.
- 5) Hepatic:
 - **Hepatitis**; 30% of addicts have enlarged, firm, non-tender livers.
 - Increased incidence of **hepatitis B and C**.
- 6) Increased incidence of **HIV infection**.
- 7) Renal: **Sclerosing glomerulo-nephritis**.
- 8) Adrenal gland dysfunction and decreased ACTH secretion from the pituitary gland.

C/P of Acute Intoxication:

The same as **morphine actions**, but **more severe** e.g. respiratory depression..... see pharmacology of anesthesia.

C/P of Withdrawal Syndrome:

- It appears after sudden cessation of the drug;
- For meperidine, it occurs after 4-5 days.

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- For heroin, it occurs after 7-10 days.
- For methadone, it occurs after 10-14 days.
- They are the **opposite of the acute effects** of the drug i.e. **opposite to morphine action** so;
- Opposite to analgesia: - Diffuse pain all over the body.
- Skeletal muscle spasm and pain.
- Opposite to the CNS action: - Anxiety, tremors, and dysphoria.
- Craving for the drug.
- Coma or convulsions.
- Opposite to the sympathetic depression action: i.e. excess sympathetic stimulation causing;
 - Dyspnea.
 - Hypertension, tachycardia.....
 - Diaphoresis i.e. increased sweating, lacrimation, and rhinorrhea.
 - Increased temperature.
- Opposite to the GIT action: - Diarrhea. - Nausea and vomiting.

C) Cannabis (Marijuana and Hashish):**C/P of Chronic Abuse:**

- Increased incidence of **sinusitis and chronic bronchitis**.

So, **intraoperative bronchospasm** is common due to airway irritation.

C/P of Acute Intoxication:

- **Conjunctival injection.**
- **Increased sympathetic activity** causing severe tachycardia, hypertension, and angina So preoperative propranolol, esmolol, or labetalol are needed.
- Euphoria with impairment of thinking, concentration and psychomotor function.

C/P of Withdrawal Syndrome:

- It is **very mild** as irritability, insomnia, diaphoresis, nausea, vomiting, and diarrhea. It rarely needs medical or pharmacological intervention.

D) Alcohol Abuse:

C/P of Chronic Abuse:.....See anesthesia with liver diseases.

C/P of Acute Intoxication:See anesthesia with liver diseases.

C/P of Withdrawal Syndrome:

- It occurs **7-10 hours** after cessation of alcohol intake (so addicted patients are likely to awaken in the morning with some signs of withdrawal). The symptoms increase gradually and become very obvious after 7-10 days, and include;
 - Delirium tremens: disorientation, increased psychomotor activity, hallucination.
 - Hand tremors.
 - Autonomic dysfunction as tachycardia, dyspnea, hyperpyrexia, anxiety, and insomnia.
 - Agitation and seizures.

Anesthetic Management:**Preoperative Assessment and Preparation:**

- 1- Recognizing an addict during the preoperative visit** is very important and very difficult as;
- 50% of patients volunteer and give the information on direct questions.
 - The other 50% are deliberately hidden their addiction, so they should be examined for signs of addiction, if suspicious, e.g. signs of addiction of cocainesee above.

2- The addicted patient may show one of the following C/Ps:**a- C/P of Chronic Abuse:**

- **All systems should be assessed**, by history, examination, and **investigations**, and the pathology detected should be managedsee above for the chronic effects of different drugs used.
- Elective or emergency surgery can be performed.

b- C/P of acute intoxication:

- **Assess and manage the C/P of acute toxicity** by initial resuscitation (Airway, Breathing, and Circulation management) e.g. severe respiratory depression of opioids.
- **Postpone elective surgery.**
- **Only perform emergency surgery, but there is an increased risk.**

c- C/P of Withdrawal Syndrome:

- **Assess and manage the C/P of withdrawal symptoms.**
- **Postpone elective surgery.**
- **Only perform emergency surgery after providing the abused substance or its substitution** e.g. • In opioid addiction, provide any other opioids, methadone, or the substance itself.
- In alcohol addiction, provide benzodiazepines.

3- Premedication:

- **Sedatives:** They are usually given with withdrawal symptoms and are avoided with acute toxicity.

Intraoperative Management:**Effect of Substance Abuse on Anesthetic Requirements:****1) Opioid, Barbiturates, Alcohol, or Benzodiazepine Abuse:** They are depressive drugs.

- **Acute toxicity: Decrease** the anesthetic requirements.
- **Chronic abuse: Increase** the anesthetic requirements.

2) Cannabis as Marijuana and Phencyclidine:

- **Acute toxicity: Decrease** the anesthetic requirements
- **Chronic abuse: No effect** on the anesthetic requirements.

3) Cocaine and Amphetamine: They are stimulatory drugs.

- **Acute toxicity: Increase** the anesthetic requirements (there is severe sympathetic stimulation)
- **Chronic abuse:** • **Decrease** the anesthetic requirements with **amphetamine**.
- **No effect** on the anesthetic requirements with **Cocaine**.

Induction:

According to the substance abused e.g.

- In cocaine abuse; - Avoid ketamine due to CVS stimulation.
- Avoid suxamethonium as both cocaine (an ester local anesthetic) and suxamethonium are metabolized by plasma cholinesterase.

Maintenance:

According to the substance abused e.g.

- In opioid abuse; - Avoid halothane due to the high incidence of liver diseases.
- Avoid opioids in maintaining anesthesia as large doses are required.
- Avoid opioid agonist/antagonist as they can precipitate an acute withdrawal reaction.

Intraoperative problems:

According to the substance abused e.g.

- In opioid abuse; - Hypotension may occur due to adreno-cortical insufficiency or malnutrition.

Postoperative Management:

1- No attempt of withdrawal from the abused drug e.g. opioids should be used **until the patient has recovered** from the surgical illness. Then the **patient is advised to a detoxification program.**

2- Pain control:

- Regional techniques are applied but care is taken in case of;
Cocaine abuse; so - Do a platelet count to exclude cocaine induced thrombocytopenia.
And - Avoid ester local anesthetics as they are metabolized by plasma cholinesterase, so they compete with cocaine leading to a decrease in the metabolism of both.
- A strong analgesic is needed.

Electro-Convulsive Therapy (ECT)

Indication: Endogenous depression (when drug therapy fails)

Physiologic Effects of ECT:**1- CVS:**

- **Parasympathetic stimulation:** It is immediate and short, causing;
 - Bradycardia (up to 30 beat/min and even asystole for 6 sec has been seen in some cases).
 - Hypotension.
 - Increased secretions.
- **Sympathetic stimulation:** It is late (after 1 min) and more sustained (for several minutes) causing;
 - Tachycardia.
 - Hypertension.
 - Arrhythmias.
 - Increased myocardial O₂ consumption that may cause myocardial ischemia unless O₂ supplementation during convulsions is given.

2- CNS: (+)

- Increased cerebral O₂ consumption.
- Increased cerebral blood flow 1.5 – 7 times the basal level.
- Increased ICT.

3- Eye:

- Increased IOP.

4- GIT:

- Increased intra-gastric pressure.

Contraindications of ECT:**A) Absolute:**

1. Recent myocardial infarction (< 3 months).
2. Recent cerebro-vascular accident (< 3 months. Some authors say < 1 month).
3. Intracranial mass lesion or increased ICP of any cause.

B) Relative:

1. CVS: Angina pectoris or CHF.
2. Lung: severe pulmonary disease.
3. Eye: Glaucoma or retinal detachment.
4. Bone: severe osteoporosis or major bone fractures.
5. Pregnancy.

Complications of ECT:

1. Headache.
2. Muscle ache.

3. Confusion and somnolence.
4. Memory loss: It may last for several weeks.

Anesthetic Management:

Preoperative Management:

1- **Preoperative assessment** of the CVS, respiratory system, CNS, eye, bones, and pregnancy to **exclude contraindications**.

2- **Preoperative fasting** for at least 6 hours (as any anesthesia). Many patients are uncooperative so, careful supervision is needed to ensure fasting.

3- **Premedications:**

- Atropine or glycopyrrolate to; - Prevent bradycardia.
- Decrease profuse secretions.

Intraoperative Management:

Induction:

- After preoxygenation, most induction agents as barbiturates, etomidate, benzodiazepines, propofol have anticonvulsant properties as they decrease the duration and increase the threshold of the electrically induced seizure. So, this decreases the therapeutic benefit of ECT. Therefore, **these agents are used in small doses only**.

• **Methohexitone:** is the drug of **choice** due to its rapid onset and short duration (i.e. early recovery).

• Thiopentone: can be used but it has a longer duration (i.e. longer recovery time).

• Propofol: is not preferred because it decreases the duration of the seizure.

• Etomidate: is not used as it produces a longer recovery time.

• Ketamine: is not used although it increases the seizure duration, as it produces a delayed recovery time, nausea, and ataxia.

- Muscle relaxants:

• Suxamethonium is most commonly used, in a smaller dose 0.5-1 mg/Kg.

• The lungs are ventilated with 100% O₂ using a face mask and either, an anesthetic breathing circuit or a self inflating bag, after induction and muscle relaxation and during the seizure till spontaneous breathing returns.

• When the limbs are flaccid, a rubber bite block is inserted between the teeth before applying the electrical stimulation.

Monitoring: Standard +

• Monitors to detect the occurrence of convulsions (seizure activity):

They are not apparent clinically due to the use of muscle relaxants.

1. **Unprocessed EEG:** It is possible with modern ECT machines.

2. **An isolated forearm technique:** As a tourniquet inflated around one arm before injection of suxamethonium. This prevents entry of the muscle relaxant into this arm.

Intraoperative Problems:

1) Patients with limited CVS reserve:

- Atropine or glycopyrrolate is given to prevent excessive bradycardia.

- Nitroglycerine, nifedipine, α and β blockers are given to control sympathetic stimulation (N.B.; high dose esmolol 200 mg can decrease the seizure duration)

2) To increase the seizure duration:

- Hyperventilation is done.

- Caffeine 125-250 mg i.v. slowly.

Recovery:

In the lateral position, by a trained nursing staff.

CHAPTER 42

ANESTHESIA FOR RADIOLOGY

Anesthesia for Radio-diagnosis

General Anesthetic Problems:

1- Anesthetic Equipments:

- In most hospitals, radiology and radiotherapy suites are not designed with anesthetic requirements e.g. the anesthetic apparatus often competes for space with bulky equipment.

- The maintenance of anesthetic equipment may be less than ideal

Therefore, **anesthetic equipments should be available** and the anesthesiologist must be precise in checking the anesthetic machine and device.

2- Monitoring Equipments:

- They may not be readily available and are often the oldest in the hospital. Even clinical observation may be limited by poor lightening.

Therefore, **monitors should be available** and the anesthesiologist must be precise in checking the monitoring equipments.

3- Patient Preparation:

- It may be inadequate because the patient comes from a ward in which the staff are unfamiliar with preoperative protocols e.g. preoperative fasting.

Therefore, **patient preparation should be revised by the anesthesiologist.**

4- Communication Between the Radiologist, Radiotherapist, and the Anesthesiologist:

- Lack of communication may result in failure to recognize the other's requirements.

5- Recovery and Resuscitation Facilities:

- They are often inadequate e.g. suction, O₂ mask, defibrillator,.....

Therefore, the radiology suite **should be equipped with these facilities.**

Anesthetic Management:

Aim of Anesthesia (Role of the Anesthesiologist)

1- To make the patient **comfortable and pain free** (in painful procedures).

2- To **prevent movement** during the procedure so as to provide improved images and results especially in **uncooperative patients** as infants, young children, adults who are confused, mentally-ill, or intellectually subnormal.

3- To take care of **claustrophobic patients** who are afraid from the closed spaces.

4- To **control the airway** in unconscious and critically-ill patients.

5- To **provide optimum conditions** for successful performance of the procedure as; **maintaining an adequate hemodynamic state.**

6- To **treat complications** of the procedure e.g. a reaction to the contrast medium.

Pre-anesthetic Management

1- **Pre-anesthetic assessment** by history, examination, and investigations as in other cases that need GA.

2- **Pre-anesthetic assessment of the system affected** e.g. **full neurologic assessment** is required to take a baseline, to compare with the patient's postoperative neurologic status, and to determine the need for invasive monitoring as ICP monitoring.

3- Premedications:

- Sedatives: - Oral midazolam 0.5 mg/Kg given in small amounts of juice, for children.
- Not preferred for outpatients, or those with ICP or decreased level of consciousness.

Intra-anesthetic Management:**Monitoring:**

- It is essential, as in most cases the patient is not readily accessible to the anesthesiologist
- Standard + according to the condition of the patient e.g.;
- In interventional neuro-radiology and head trauma, CNS monitors are needed as EEG, SSEPs, MEPs, trans-cranial Doppler, and ¹³³Xenon CBF monitoring.

Choice of Anesthesia**A) Conscious Sedation:** (It may be needed for hours)

Uses: In cooperative patients.

Advantages:

- It allows an awake neurologic assessment of the patient e.g. during interventional neuro-radiology.
- There are no pressor responses of intubation and extubation.

Disadvantages:

- Poor control of the airway in unconscious patients.
- Poor tolerance of induced hypotension in an awake patient if needed e.g. in interventional neuro-radiology.
- Time is lost in induction of GA and securing the airway, when needed during emergency situations e.g. emergency craniotomy.
- It is not suitable for patients with increased ICP.
- Some movement may occur during the procedure.

Technique:

- Degree of sedation.....see anesthesia for pediatric patients.
- E.g.;
- Chloral hydrate 50 mg/Kg oral or rectal.
- Propofol i.v. boluses or infusion.

B) General Anesthesia

Uses: • In uncooperative patients.

Advantages: They are the opposite to the disadvantages of the sedative technique.

Disadvantages: They are the opposite to the advantages of the sedative technique.

Technique: By;

a- **TIVA:** It needs no scavenging system. It is done by either;

• Propofol i.v. anesthesia:

- Advantages:
- Allows rapid recovery so suitable for outpatient anesthesia.
 - Prevents movement of the patient during the procedure.
 - Does not increase ICP.
 - No hallucinations or Myoclonic movements.

• Ketamine i.v. boluses:

Disadvantages: They are the opposite to the advantages of propofol anesthesia.

b- **Inhalational Anesthesia:** It needs a scavenging system. It is done either by; **halothane or sevoflurane.**

Airway Management:

Airway must be secured in unconscious or anesthetized patients by either an ETT or a laryngeal mask.

ANESTHESIA FOR RADIOLOGY

Ventilation: It can be either spontaneous or controlled according to the patient's need.

Controlled ventilation (mild hyperventilation) is needed in some patients with **increased ICP**, to produce slight hypocapnia i.e. **maintain the PaCO₂ at about 28-30 mm Hg** to produce VC so as to;

- Decrease the ICP.
- Decrease the CBF and slow the cerebral circulation; this will;
 - Prolong the contrast transit time allowing better delineation of small vascular lesions.
 - Allow the embolic liquid adhesive more time to polymerize inside the A-V malformation during interventional neuro-radiology, decreasing the possibility of distal embolization.

Post-anesthetic Management:

Complete recovery of the patient before transport to the ward is essential.

Special Considerations**Magnetic Resonance Imaging (MRI):**

Anesthetic Problems: Beside the general anesthetic problems and management;

1- Attraction of Ferromagnetic Objects to the Magnetic Field of an MRI: So;

- There is a risk to the patient of **dislodgement of implanted metallic objects** as vascular clips, cochlear implants, and interventional radiology devices as coils, filters, or stents.
- There is a risk of **injury to the patient and personnel, and a risk of damage of equipments** by ferromagnetic objects attracted to the magnetic field e.g. pens, keys, scissors, laryngoscopes, stethoscopes, paper clips, vials, and needles.

Therefore; • Everyone coming near an MRI scanner should be carefully screened for ferromagnetic objects.

- The monitors should be either placed at least 5-8 feet from the magnet bore or permanently fixed.

- MRI-compatible equipment e.g. ECG electrodes, laryngoscopes

2- Malfunction of Electronic Equipments by the Peripheral Field of the Magnet:

E.g.; - Demand cardiac pacemaker.

- Artificial heart valves (especially pre-6000 Starr-Edwards) (other valves are safe).
- Other implanted electronic devices as automatic implantable cardiac defibrillators, implantable infusion pumps, or neuro-stimulators.
- Computer discs or magnetic tapes on credit cards.
- Monitors and infusion pumps.

Therefore; • MRI-compatible monitors (that use shielding and non-ferromagnetic components) should be used as both MRI and monitors affect each other.

N.B.; Orthodontic braces, dentures, and tattoos or cosmetics that contain metallic dyes, although they are safe, they can degrade the image quality.

3- Heating of Objects:

E.g. • Patients with large metal implants.

- Pulse oximeter probes and ECG cables.

There is a risk of excessive heat at these sites that may cause thermal injury.

To decrease the risk of burns;

- **Monitoring the temperature** at the site is very important.
- **Inspect the insulation** on all monitoring wires to ensure that it is intact.
- Place cables and lead wires in **straight alignment** (do not allow monitoring wires to form loops).

- Remove all leads or wires, that are not being used.
- Separate cables from patient's skin.
- Keep cables and sensors out of the scanning area e.g. place a pulse oximeter probe on the toe of a patient whose chest is being examined.
- Avoid excessive power.

4- MRI Tube:

After induction of anesthesia outside the MRI scanner, the patient is often far from the anesthesiologist inside the MRI tube. This carries the following risks;

- The relatively small bore of the MRI tube makes entrance of **obese patients impossible**. Most MRI tables can carry up to 120 Kg body weight. Recently an open MRI has been available, that can carry more obese patients.
- The narrow space inside the tube creates a feeling of **claustrophobia** (fear of closed space) in some patients.
- I.v. lines, anesthetic circuits, O₂ tubing, and monitor cables must be of sufficient length to reach the patient deep inside the scanner tube.
- Access of the airway is limited, so a disconnection alarm is preferred.
- Body temperature monitoring is needed, as airflow via the scanner tube increases heat loss causing hypothermia especially in pediatric patients. Non-ferromagnetic temperature strips, axillary, rectal or esophageal probes are used.

5- ECG Changes produced by the Magnetic field of MRI:

They include T wave and late ST segment changes (like the ECG changes of hyperkalemia or pericarditis). These changes have no physiologic significance.

6- Effect on Personnel:

- There is **no ionizing radiation** or its hazards therefore the anesthesiologist may approach the patient safely.
- But, **controversy** is still present as regards to its effect (other than ionizing radiation hazards) on patients, health care personnel, and pregnant females. Till now no significant deleterious effects have been proved, but **caution is recommended (especially for pregnant females)**.

Anesthesia for Radiotherapy

Typically sessions are 20-30 minutes daily for 4-6 weeks during which no movement of the patient is required.

Indications of GA:

- 1- To prevent movement during radiotherapy treatment in children or uncooperative adults.
- 2- To allow insertion of radio-active sources locally, is treating some types of tumors e.g. carcinoma of the cervix, tongue, or breast.

Anesthetic Problems:

Beside the general anesthetic problems of radio-diagnosissee before +

- 1- The patient should be **alone** in the radiotherapy room, but **immediate access to the patient is required** in emergency conditions.
- 2- I.v. access: e.g. **Hickmann line** is needed for repeated daily anesthesia, as finding a peripheral vein is very difficult especially in children.
- 3- **Monitoring is very difficult** because;
 - The patient remains alone.
 - Semi-darkness is present.

It is done via standard monitoring as ECG, NIBP, pulse oximetry with the help of

- A closed-circuit television screen to assess respiratory movements and monitors
- A microphone to transmit - The audible ECG signals
and - The saturation-dictated pitch of the oximeter signals.

ANESTHESIA FOR RADIOLOGY**Anesthetic Techniques:**

The same as anesthesia for radio-diagnosis with the following precautions;

a- Inhalational Anesthesia: Due to repeated exposure to GA every day for several weeks;

- A laryngeal mask is preferred than the ETT.
- Halothane is contraindicated in adults due to the liability of liver dysfunction.

In children, halothane can still be used as the risk of hepatic dysfunction is very low.

Sevoflurane is a good choice nowadays.

b- I.v./i.m. ketamine: can be used but has the following disadvantages:

- Excessive salivation.
- Tachyphylaxis with repeated use.
- Sudden purposeless movements.
- Risk of airway obstruction or laryngospasm.
- Delayed recovery as the patients are managed as outpatients.

Q: What are the precautions of administration of anesthesia every day for one month?

What are the precautions of repeated exposure to anesthesia?

CHAPTER 43

ANESTHESIA & INFECTIOUS DISEASES

The Most Common Infectious Diseases are;

1- Pneumonia and Upper Respiratory Tract Infection (URTI)

- Anesthetic precautionssee anesthesia for pediatric patients.

2- Intravenous Catheter Infection:

- It is caused mainly by Staphylococci Epidermidis.
- Culture and sensitivity from the removed catheters may be done. It should be changed frequently, usually every 72 hours.

3- Gastroenteritis:

It maybe associated with dehydration and electrolyte disturbances.

4- Tetanus:

- It is caused by Clostridium Tetani.
- It causes; • Muscle spasm e.g.;
 - The masseter muscle, causing trismus or lock jaw.
 - Laryngeal spasm after extubation.
 - Intercostal and diaphragmatic spasm causing interference with ventilation.
 - Sympathetic stimulation as tachycardia, hypertension, and arrhythmias.

So, • Antitoxin treatment is needed before anesthesia.

- Epidural anesthesia is preferred as it decreases sympathetic activity.

5- Tuberculosis (T.B.):

- It is caused by mycobacteria tuberculosis.
- It causes; • Respiratory tuberculosis.
 - Neurologic tuberculosis.
 - Gastrointestinal tuberculosis.

6- Acquired Immune Deficiency Syndrome (AIDS):

- It is caused by; HIV-I and HIV-II that are transmitted by sexual contacts, blood products, and i.v. drug users.
- They cause; • CNS: Encephalitis, peripheral neuropathy, and meningitis.
 - Heart: Cardiomyopathy.
 - Renal: Dysfunction.
 - Adrenal: Insufficiency.
 - Blood: Thrombocytopenia and anemia.
 - Opportunistic infections: as pneumocystic carinii (pneumonia), candidiasis, tuberculosis.....
 - Skin: Kaposi sarcoma.

12- Hepatitis:- It is caused by virus B, C, and D. They cause liver cirrhosis.

13- Septic Shock:See ICU.

14- Infective Endocarditis:See anesthesia and cardiovascular diseases.

CHAPTER 44

ANESTHESIA & CANCER

Patho-physiologic Manifestations of Cancer

(Para-neoplastic Syndrome)

1- Fever, anorexia, and weight loss.

2- Hematologic abnormalities:

- **Anemia** due to GIT ulcerations, or bone marrow depression by chemo-therapy.
- **Pancytopenia** especially carcinoma of the breast.
- **Polycythemia** due to increased erythropoietin especially in hepatoma and hypernephroma.
- **Thrombocytopenia.**
- **DIC** in advanced cancer.

3- Neuro-muscular Abnormalities:

- **Skeletal muscle weakness (Myasthenic syndrome)** with lung cancer So, care is taken with muscle relaxants.

4- Ectopic hormone production: E.g.

- **Small cell carcinoma of the lung** releases; - **ACTH** that causes Cushing syndrome.
- **ADH** that causes water intoxication.
- **Thyroid (Medullary) carcinoma** releases; - **ACTH** that causes Cushing syndrome.
- **Thyro-calcitonin** that causes hypocalcemia.

5- **Hypercalcemia** due to bone secondaries.

6- **Tumor lysis syndrome:**

Due to sudden therapeutic destruction of tumor cells. This causes;

- **Hyper-uricemia** which leads to **acute renal failure.**
- **Hyperkalemia** which leads to arrhythmias.
- **Hyper-phosphatemia** which leads to secondary hypocalcemia.

7- **Adrenal insufficiency:**

Due to- Secondaries in adrenal glands.

- Suppression of the adrenal cortex by prolonged treatment with corticosteroids.

8- **Renal complications:**

Due to; • Secondaries.

- **Hyper-uricemia.**
- **Chemotherapy** especially methotrexate and cisplatin.
- **Ag-Ab reaction** that causes nephrotic syndrome.
- **Ureteric obstruction.**

9- **Acute respiratory complications:**

Due to; • Tumor extension.

- **Chemotherapy** especially bleomycin that causes interstitial lung fibrosis.

10- **Acute cardiac complications:**

As; • **Pericardial effusion and pericardial tamponade** due to secondaries involving the pericardium especially in lung cancer.

- **AF and flutter** due to secondaries, involving the myocardium.
- **Cardiomyopathy** due to doxorubicin or daunorubicin.
- **SVC obstruction** due to extension of the tumor especially carcinoma of the lung.

11- **Spinal cord compression:**

Due to secondaries, mainly in the epidural space, common with lung and breast cancers.

12- Increased ICP:

Due to secondaries, especially in carcinoma of the lung and breast.

Anesthetic Management:**Preoperative Evaluation:**

- 1- Evaluate the **cancer** and its extension, **para-neoplastic symptoms** as above.....
- 2- **Psychologic support** is needed therefore, be sympathetic in dealing with cancer patients. Despite their appearances, these patients are frightened.
- 3- Preoperative management of;
 - **Cancer induced pain** that needs opioids.
 - **Nutrient deficiency.**
 - **Venous access** which may be a real challenge.
- 4- **Perioperative steroid cover** when steroids are used in conjunction with chemotherapy.
- 5- Preoperative assessment of **complications of irradiation** as fibrosis especially;
 - In the airway, that may lead to difficult intubation
 - In the GIT, that may lead to persistent vomiting.
 - In joints, that may lead to stiff joints.
- 6- Preoperative assessment of **side effects of cancer chemo-therapeutic agents:**
 1. **Immuno-suppression:** With all agents especially cyclo-phosphamide, methotrexate, fluorouracil. So, a strict aseptic technique is used.
 2. Blood: as **anemia, leucopenia, and thrombocytopenia** occur with all agents especially with methotrexate, fluorouracil, and mithramycin.
 3. **Cardiomyopathy:** By doxorubicin and daunorubicin.
 4. **Interstitial pulmonary fibrosis:** By bleomycin and busulfan.
 5. **Renal toxicity:** By methotrexate, mithramycin, cisplatin, and busulfan.
 6. **Hepatic toxicity:** By 6- mercapto-purine.
 7. **CNS toxicity:** By mithramycin.
 8. **Peripheral nervous system toxicity:** By vincristin and vinblastin.
 9. **Autonomic nervous system toxicity:** By vincristin and vinblastin.
 10. **Stomatitis:** With all, especially methotrexate, fluorouracil, bleomycin, and mithramycin.
 11. **Plasma cholinesterase inhibition** by cyclo-phosphamide and methotrexate.

Common Cancers

- Carcinoma of the lung, breast, colon, prostate, liver, esophagus, and pheochromocytoma.

CHAPTER 45

ANESTHESIA & IMMUNE SYSTEM DYSFUNCTION

1) Allergic reactions: E.g. drugs.

.....See Anesthetic problems.

2) Resistance to Infection:

• **Local and inhaled anesthetics especially N₂O produce dose-dependent inhibition of mobilization and migration of leucocytes.** This increases the incidence postoperative infection and augments a coexisting infection.

• **Regional anesthesia and deep GA decrease the stress humoral response to surgical stimuli i.e. less cortisol and CAs are released that may improve immunity.**

3) Auto-immune Diseases:

There are Abs that attack self-Ags (i.e. tissues of the host himself).

E.g. of autoimmune diseases;

a- Organ-specific Diseases:

1. DM type I.
2. Myasthenia gravis.
3. Grave's disease.
4. Hashimoto's thyroiditis.
5. Addison's disease.
6. Chronic active hepatitis.
7. Auto-immune hemolytic anemia.

b- Systemic Diseases:

1. Rheumatic fever.
2. Rheumatoid arthritis.
3. Ankylosing Spondylitis.
4. Systemic lupus erythematosus.
5. Scleroderma.
6. Nephrotic syndrome.
7. Chronic graft-versus-host disease.
8. Sarcoidosis.

CHAPTER 46

CARDIO-PULMONARY RESUSCITATION

Indications of Cardio-Pulmonary Resuscitation (CPR)

At any time an individual cannot adequately oxygenate or perfuse vital organs (especially the brain). This usually occurs after cardiac arrest, respiratory arrest or combination of both. N.B.; the cerebral cortex is damaged permanently by ischemia of 3-4 minutes duration.

Signs of Cardiac Arrest:

- 1) sudden deep unconsciousness.
 - 2) Absent major vessel (carotid and femoral) pulses.
- Both 1 and 2 are sufficient to justify the diagnosis.
- 3) Dilated pupils.....
 - 4) Ashen cyanosis.....
 - 5) Apnea or grasping.....
- } → These are unreliable signs.

CPR Management (Chain of Survival Concept) by;

- The American Heart Association and the International Liaison Committee on Resuscitation.
- The European Resuscitation Council.

At first, before initial resuscitation;

- **Initial clinical assessment** of the patient and level of responsiveness by gently shaking the patient and shouting (*Are you all right?*)
- **Call for help** either by telephone call, by shouting... This decreases the time before the first defibrillation and hastens the delivery of advanced life support.

Then Emergency Cardiac Care Algorithm and Basic Life Support (BLS) is initiated.

N.B.;

Basic Life Support (BLS): It is life support without the use of special equipment.

Primary ABCD Survey: It is the primary assessment of A: Airway.

B: Breathing.

C: Circulation and Chest compression.

D: Defibrillator.

Advanced Cardiac Life Support (ACLS): It is life support with the use of special equipment.

Initial Resuscitation:

A) Airway:

The patient is positioned supine on a firm surface.

a) Basic Techniques:

- 1- **Head tilt-chin lift** (figure 46-1).
- 2- **Jaw-thrust** (figure 46-1):
 - It is done to remove obstruction produced by falling of the tongue (posterior placement)
 - It is done without a head-tilt, if a cervical spine injury is suspected.
- 3- Sweep out **vomit or foreign bodies visible in the mouth** by the index finger in unconscious patients only (N.B.; placing a finger in the mouth of a conscious or convulsing patient is not recommended).

CARDIOPULMONARY RESUSCITATION

Head tilt-chin lift



Jaw-thrust

Figure 46-1

4- Heimlich maneuver:

- If the patient is conscious and/or the foreign body cannot be removed by a finger sweep. It is either done while the patient is standing or lying down.
- This sub-diaphragmatic abdominal thrust elevates the diaphragm expelling a blast of air from the lungs that displaces the foreign body (figure 46-2).
- Complications:
 - Rib fracture.
 - Trauma to the internal viscera.
 - Regurgitation.

N.B.; In infants, a combination of back blows and chest thrusts are done.

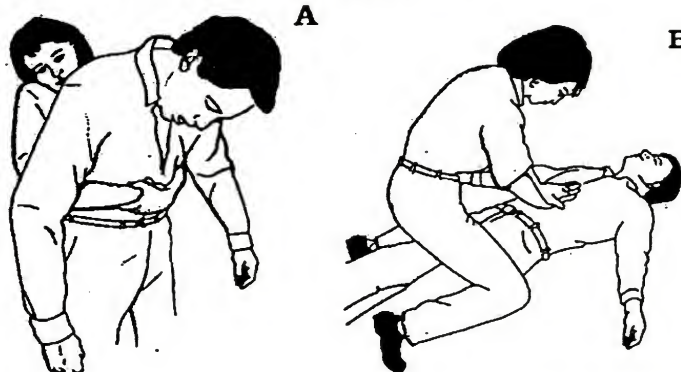


Figure 46-2; Heimlich maneuver can be performed with the victim Standing (A) or lying down (B)

b) Advanced Techniques + Good suction.

- 1- Oral and nasopharyngeal airways.
- 2- Endo-tracheal tubes.
- 3- Combi-tubes.
- 4- Crico-thyrotomy (Crico-thyroidotomy):

B) Breathing:

- Apnea is confirmed by:
 - **Look:** to see chest wall movements (A see-saw movement of the abdomen indicates airway obstruction).
 - **Listen:** to breath sounds from the mouth.
 - **Feel:** the airflow.
- Initially, 2 breaths are slowly administered (1.5-2 seconds per breath in adults, 1-1.5 seconds in infants and children). If these breaths cannot be delivered, the airway is still obstructed needing further management as above.
- Breathing is then managed as follows; (+ cricoid pressure \pm 100% O₂).

1- Mouth-to-mouth or mouth to mask (mouth to barrier-device):

- With the airway held open, pinch the nostrils closed, take a full breath and seal your lips over the patient's mouth. Blow steadily into the patient's mouth, watching the chest rise as if the patient was taking a deep breath. Each breath should take about 2 seconds for a full inflation. Then allow passive expiration of the patient (figure 46-3).

- Precautions:

- Successful breathing is achieved at 800-1200 mL tidal volume, 10-12 times/min in adults.
- A rescuer's exhaled air has an O₂ concentration of only 16-17% (better than no O₂) so, supplemental 100%O₂ should be always used as soon as possible.

N.B.; Mouth to mouth-and nose is used in infants and small children.

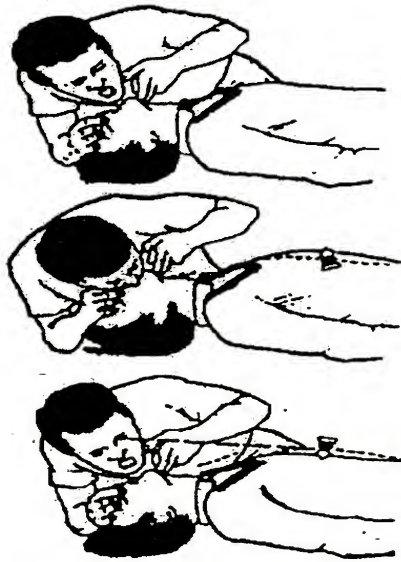


Figure 46-3; Mouth to mouth breathing

2- A self-inflating bag-valve-mask or endotracheal tube:**3- Ventilators:**

.....See Intensive Care.

C) Circulation:**1) External (Closed) Chest Compression:**

(by Kouwenhoven, Jude, and Knickerbockers in 1963)

Technique:

The xiphoid process is located and the palm of the rescuer's hand is placed over the lower half of the sternum, 2 fingers breadth above the xiphisternum. The other hand is placed over the hand on the sternum, with the fingers interlaced or extended. The rescuer's shoulders should be positioned directly over the hands, with the elbows locked into position and arms extended, so that the weight of the upper body is used for compression. With a straight downward thrust, the sternum is depressed 4-6 cm in adults, 2-4 cm in children, 1-2 cm in infants (by the middle and ring fingers on the sternum, one-finger breadth below the nipple line. Compression and release times should be equal. It is applied for any pulseless patient.

Physiology (Mechanism) of External Chest Compression:**1- Thoracic Pump Theory:** (The most accepted)

A rise in intra-thoracic pressure is transmitted to extra-thoracic arteries (being thick walled, they retain and transmit this pressure), but not to thinner-walled extra-thoracic veins, which tend to collapse. The resulting extra-thoracic arterio-venous pressure gradient causes forward blood flow i.e. the heart is passive.

CARDIOPULMONARY RESUSCITATION**2- Cardiac Pump Theory:**

Compression of the heart between the sternum and the spine is responsible for forward blood flow.

There is controversy between both theories.

Assessment of the Adequacy of the Circulation During CPR:

Properly performed chest compression (\pm vasoconstrictors)

a- Hemodynamic Parameters: They should be maintained as follows;

- Systolic ABP : 60-80 mm Hg.
- Diastolic ABP: > 40 mm Hg.
- CO : 25-33% of the normal.
- Blood flow : - Brain 50-90% of the normal.
- Heart 20-50% of the normal.
- Lower limb 5% of the normal.

i.e. chest compression will maintain blood flow mainly to the upper 1/2 of the body.

• Coronary perfusion occurs primarily during the relaxation phase (diastole) of chest compression. The critical myocardial blood flow (15-30 mL/min/100 gm) is reached when the aortic (diastolic) pressure exceeds 40 mm Hg, or the myocardial perfusion pressure (diastolic aortic pressure – Right atrial diastolic pressure) exceeds 20-25 mm Hg. When CPR is conducted in patients, with invasive monitoring present, efforts should be made to obtain these pressures by optimizing the chest compression technique and/or administration of epinephrine.

b- ET CO₂ Level:

After intubation, CO₂ excretion during CPR is dependent primarily on blood flow rather than on ventilation.

- During low flow states "Low CO" (i.e. unsuccessful CPR); The ET CO₂ is usually < 10 mm Hg.
- During high flow states "High CO" (i.e. successful CPR); The ET CO₂ is usually > 20 mm Hg.
- When spontaneous circulation resumes, the earliest sign is a sudden increase in the ET CO₂ > 40 mm Hg.

This also is used to detect the prognosis of CPR.

N.B.; NaHCO₃ administration liberates CO₂ in the venous blood and a temporary rise in ET CO₂ occurs. Therefore, ET CO₂ monitoring will not be useful for judging the effectiveness of chest compression within 3-5 minutes after NaCO₃ administration.

2) Invasive Cardio-Pulmonary Resuscitation:

It is done either by; • Thoracotomy and open-chest cardiac massage.

Or • Emergency cardio-pulmonary bypass (via the femoral artery and vein).

Indications:

It is not routinely done, but it is indicated when CPR is needed in the following conditions;

- Penetrating or blunt chest or abdominal trauma.
- Severe chest deformity.
- Pericardial tamponade.
- Pulmonary embolism.
- Open cardiac surgery.

3) Intravenous Access:

It is either through;

a- A preexisting internal jugular or subclavian line:

- It is ideal in CPR. If it is not present, its insertion will be time consuming, but if

the peripheral line is inadequate, it will be mandatory.

Or b- A peripheral i.v. sites:

- This is associated with a **significant delay between drug administration and delivery to the heart**, since peripheral blood flow is drastically reduced during resuscitation. **So, after drug administration, it should be followed by an i.v. flush** (e.g. a 20-mL fluid bolus in adults) and elevation of the extremities to ensure delivery to the central circulation.
- Antecubital or femoral lines are preferred than the dorsal hand or saphenous sites.

Alternative Routes:

1- Endotracheal (via an ETT):

- Some drugs are well absorbed e.g. lidocaine, epinephrine, atropine, and naloxone "LEAN" (not NaHCO_3).
- These drugs are delivered down a catheter whose tip extends past the ETT bevel.
- Dose: 2- 2 ½ times higher than i.v. doses, diluted in 10 mL of normal saline.

2- Intraosseus Infusion:

- It is used specially in children < 6 years of age, but can be used in all ages.
- A rigid **18- gauge spinal needle** with a stylet or a small bone marrow trephine needle is inserted into the **distal femur or proximal tibia** (figure 46-4). Once the needle is advanced through the cortex, it should stand upright without support. **Proper placement is confirmed by the ability to aspirate marrow through the needle and a smooth infusion of fluid.**

Tibial interosseus access

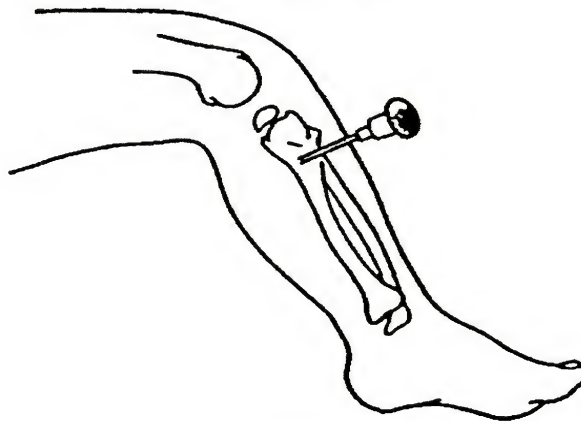


Figure 46-4; Intraosseus infusion

- It should be replaced by the i.v. route as soon as possible.

4) Dysrhythmia Recognition:

- During CPR, ECG monitoring and strips are essential to determine the type of dysrhythmia to determine the specific management required.
- Interpreting rhythm strips and monitoring during CPR are complicated by artifacts.
- See later for protocols of management.....

5) Drug Administration During CPR:

1- Vasopressors:

Epinephrine:

- It is the drug of choice.

Action (During CPR):

- α adrenergic agonist:** • This is the **most important action**.

CARDIOPULMONARY RESUSCITATION

- When given during chest compression, epinephrine increases the coronary perfusion pressure, enough to provide myocardial blood flow, for restoration of spontaneous circulation.
- If invasive monitoring is present during CPR, chest compression and/or vasopressors are needed if;

- The arterial diastolic pressure is < 40 mm Hg.

- Or – The myocardial perfusion pressure is < 20 mm Hg.

But because most cardio-pulmonary resuscitations occur without invasive monitoring, **epinephrine must be given empirically with chest compressions.**

- Studies show **all vasopressors** (α agonist or non-adrenergic vasopressors) to be **equally successful** in resuscitation regardless of β adrenergic activity.

N.B.: β adrenergic action:

- It has no effect on resuscitation as a pure β agonist drug has the same effect as a placebo.

Dose: there are many doses of epinephrine used during CPR.

1- **The standard dose:** 0.01-0.02 mg/kg i.v. push every 3-5 min (i.e. 1.0 mg).

2- **The intermediate dose :** 2-5 mg i.v. push every 3-5 min.

3- **The escalating dose** : 1 mg – 3 mg – 5 mg i.v. push, 3 min apart.

4- **The high dose** : 0.1 mg/kg i.v. push every 3-5 min. This dose is used when the standard dose fails so, it is used, usually late in CPR, as a rescue therapy because it has many disadvantages;

- It increases the incidence of death early after resuscitation, due to tachyarrhythmias and hypertension.
- Studies show that survival rates and neurologic outcome do not differ between high and standard doses.

2- Anti-arrhythmic Drugs:

As; • Atropine.

• Adenosine.

• Bretyllium.

• Epinephrine.

• Isoproterenol.

• Lidocaine.

• Magnesium in Mg deficiency.

• Procainamide.

• Verapamil.

3- Calcium Chloride:

- It is only given, usually 2-4 mg/kg, in case of;
 - Documented hypocalcemia
 - Hyperkalemia.
 - Hypermagnesemia.
 - Calcium channel blocker overdose.

4- NaHCO₃:

- Uses: It is **not routinely given**. It is only used if there is;
 - Preexisting metabolic acidosis.
 - Preexisting hyperkalemia.
 - Overdose of tricyclic anti-depressants or phenobarbitone.
 - Prolonged arrest.
- Dose: It is given by the i.v. route either;

The dose = $\frac{\text{Base deficit}}{3} \times \text{Body weight (Kg)}$ in mmol NaHCO₃.

Or it is given empirically 1 mmol/Kg.

N.B.; A 50 mL ampoule of 8.4% NaHCO₃ is a molar solution i.e. its concentration is 1 mmol HCO₃ ions/1 mL of the solution.

N.B.; Any residual NaHCO₃ should be flushed from the i.v. line, because it inactivates subsequently administered adrenaline.

- Disadvantages:

- NaHCO_3 combines with hydrogen ions to form carbonic acid which readily dissociates to CO_2 and H_2O leading to a **temporarily increase in PaCO_2** until excess CO_2 is eliminated through the lungs. CO_2 readily diffuses across cell membranes and BBB (while NaHCO_3 diffuses much more slowly). This results in increased intracellular tissue acidosis and cerebral acidosis, but there is still controversy to whether this occurs during CPR or not.
- Hyper-osmolality and hypernatremia.
- It shifts the Oxy-Hb dissociation curve to the left and decreases O_2 release.

5- I.v. Fluid Therapy:

- Colloids or crystalloids are indicated in patients with intravascular volume depletion.
- **Avoid;** • **Dextrose-containing solutions** as they cause hyper-osmotic diuresis and may worsen the neurologic outcome (unless there is documented hypoglycemia).
- **Free water solutions** e.g. D_5W as they cause cerebral edema.

6- Emergency Pacemaker Therapy:

.....see before Anesthesia with Cardiovascular diseases.

D) Defibrillation and Cardioversion:

.....see before Anesthesia with Cardiovascular diseases.

Algorithms for Management of Disorders of the Cardiac Rhythm Associated with Cardiac Arrest:

Four types of disorders may occur;

- 1- **Ventricular Fibrillation (VF):** It is the commonest cause of sudden cardiac death.
- 2- **Pulseless Ventricular Tachycardia (VT).**
- 3- **Asystole.**
- 4- **Electro-Mechanical Dissociation (EMD) = Pulseless Electrical Activity (PEA).**
It is the presence of a rhythm on the monitor without a detectable pulse.
It includes:
 - Electro-mechanical dissociation (EMD).
 - Pseudo-EMD.
 - Idio-ventricular rhythm.
 - Ventricular escape rhythm.
 - Brady-systolic rhythm.
 - Post-defibrillation idio-ventricular rhythm.

Assess responsiveness

If unresponsive ↓

Begin Primary ABCD Survey (BLS Algorithm)

- Activate the emergency response system.
- Call for a defibrillator

↓

Assess **A: Airway** for patency.

B: Breathing (by *look, listen, and feel*)

If the patient is not breathing, give 2 slow breaths.
and provide +ve pressure ventilation.

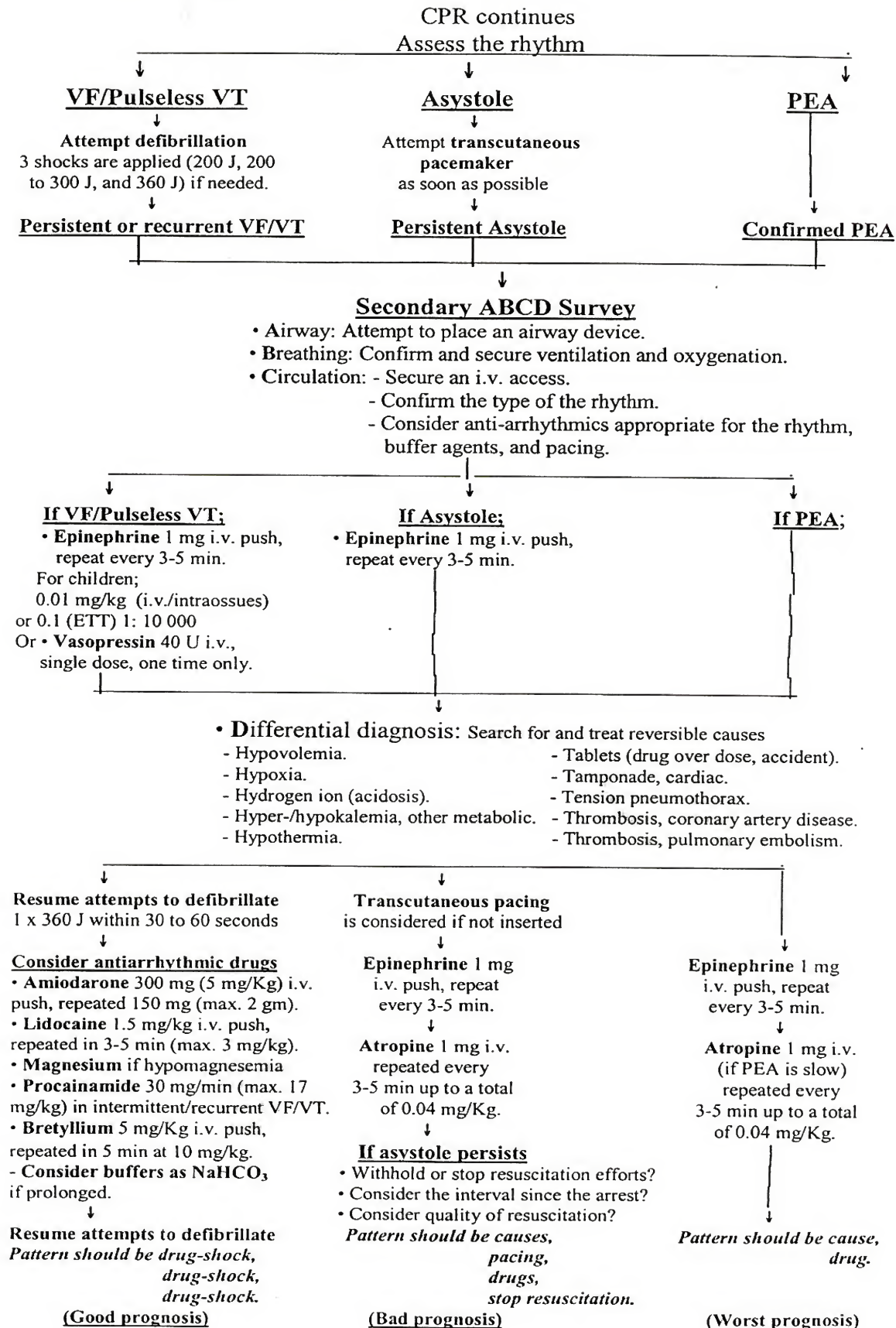
C: Circulation by assessing the pulse.

If not present, start **Chest compression**.

A precordial thump is tried if appropriate.

D: Defibrillator (and monitor) are attached when available.

↓

CARDIOPULMONARY RESUSCITATION

Post-Resuscitation Care (After Care)

- Resuscitated patients require post-CPR care which should be in a specialized unit as a **intensive care unit** or a **coronary care unit**. It includes;

1- Careful monitoring of vital functions.

2- Correction of possible cause to avoid recurrence e.g. s. electrolytes.

3- C.V.S. Support:

a) Management of **hypotension, shock and acute pulmonary edema**.

.....See before Anesthesia and Cardiovascular diseases.

b) Management of **rhythm and rate disorders**:

As; • Bradyarrhythmias.

• Tachyarrhythmias.

4- Respiratory System Support:

- During CPR, lung dysfunction can occur due to;

1- Aspiration of the vomitus.

2- Lung contusion.

3- Fractured rib.

4- Pneumothorax.

5- Pulmonary edema due to; • Heart failure.

• Head injury.

• Near drowning.

• Smoke inhalation.

- Management:

1. O₂ therapy for 24 hours after any episode of circulatory arrest.

2. Artificial ventilation may be needed according to the patient's status. AB gases, and chest x-ray are done.....see respiratory failure management.

5- CNS Support:

After CPR, the patient is either;

• Quickly regaining consciousness:

This occurs if **efficient resuscitation** was started **immediately** after a circulatory arrest and was continued until the restoration of an adequate spontaneous CO.

• Delayed recovery:

This usually occurs after; • Prolonged arrest.

Or • GA was involved.

• Failure of recovering consciousness:

This usually occurs after; • Persistence of low CO states.

• Brain damage, if; - CPR was delayed.

- Circulatory arrest was precipitated by hypoxemia.

N.B.; Good recovery has taken place after 1-2 hours of continuous CPR.

Management of brain damage after CPR:

(The same as cerebral protectionsee Anesthesia For Neurologic Diseases)

a- General Measures:

1. **Continue ABCs:** Airway, Breathing, and Circulation (ABP and HR).

2. **Anticonvulsants:** to control epileptic-form fits which increase the CMRO₂.

3. Keep the Hct at the low normal range to **decrease blood viscosity**.

4. **Correct electrolyte, acid- base imbalance, and dehydration.**

5. **Assess the depth of coma** regularly.

b- Special Measures:

1. **Keep head-up tilts** to assess cerebral venous drainage.

CARDIOPULMONARY RESUSCITATION

2. **Hyperventilation** to keep the PaCO_2 at 25-30 mm Hg. There is no evidence that cerebral damage after cardiac arrest is decreased by hyperventilation, if the patient is able to achieve adequate gas exchange when breathing spontaneously.
3. **Osmotic diuretics** e.g. mannitol or **loop diuretics** e.g. furosemide.
4. **Steroids**
5. **Barbiturates and CNS depressants** e.g. thiopental or diazepam.
6. **Ca^{++} channel blockers.**

For steroids, barbiturates, and Ca^{++} channel blockers, there is no evidence that they are beneficial for cerebral damage after cardiac arrest.

6- Rehabilitation.

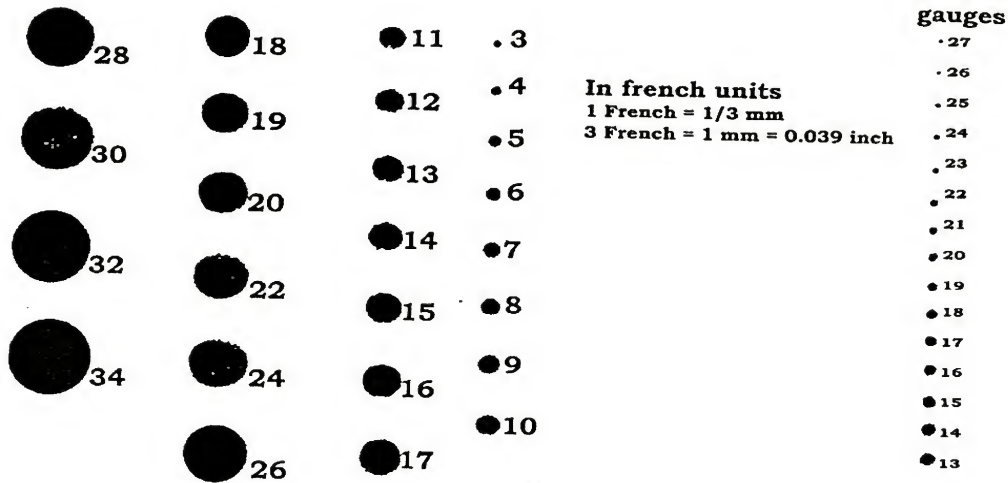
Q: Discuss post-cardiac arrest cerebral resuscitation?

APPENDIX

UK National Triage Scale

1	Immediate resuscitation	Patients in need of immediate treatment for preservation of life.
2	Very urgent	Seriously ill or injured patients whose lives are not in immediate danger
3	Urgent	Patients with serious problems but apparently stable condition.
4	Standard	Standard cases without immediate danger or distress.
5	Non-urgent	Patients whose conditions are not true accidents or emergencies.

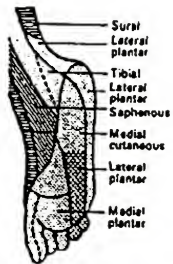
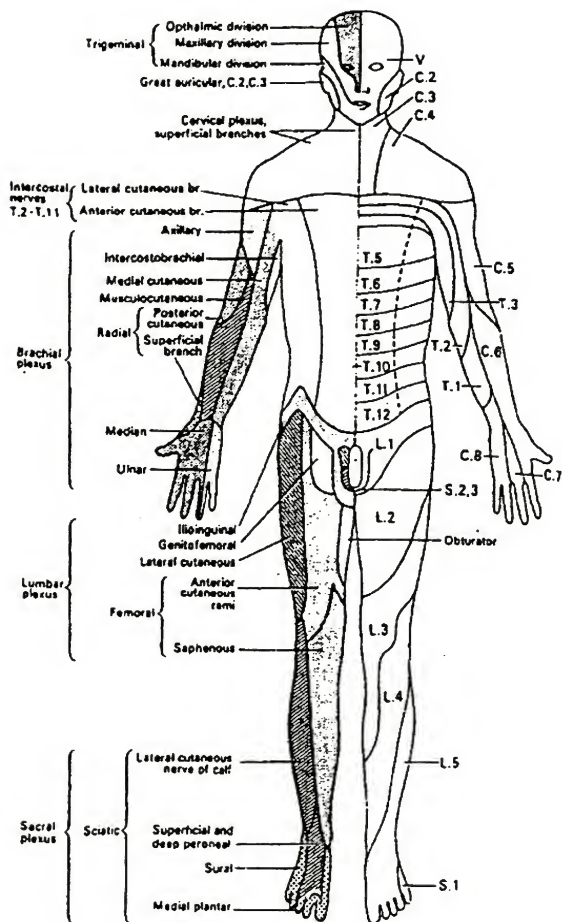
French Scale



French Scale = External Circumference.
 $= \pi \times \text{External Diameter}$
 $= 22/7 \times \text{External Diameter}$
 i.e. 1 French scale = 1/3 mm.

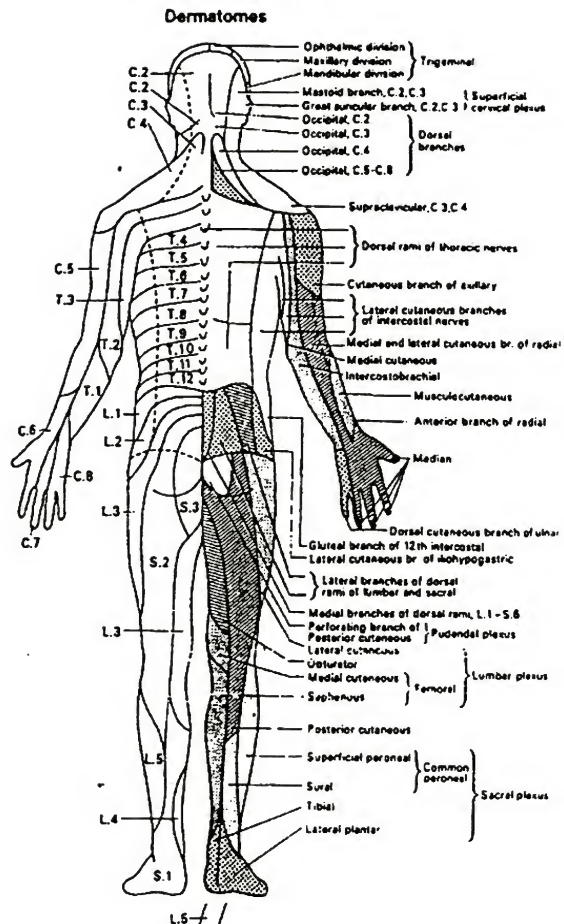
Dermatomes

Dermatomes front



ANTERIOR ASPECT

Dermatomes back



POSTERIOR ASPECT

Abbreviations

ū	Mixed venous.	CCBs	Calcium channel blockers.
ē	Electron.	CēO ₂	End pulmonary capillary oxygen content.
(-)	Inhibit.	CCP	Casualty collection point.
(+)	Stimulate.	CFAM	Cerebral function analyzing monitor.
+ve	Positive.	CFM	Cerebral function monitor.
↑	increase.	CHD	Congenital heart disease.
→	lead to.	CHF	Congestive heart failure.
↓	decrease.	CHFV	Combined high frequency ventilation.
μ	Micro.	CI	Cardiac index.
-ve	Negative.	CK	Creatine kinase.
°C	Celsius degree.	Cl ⁻	Chloride.
[]	Concentration.	cm	Centimeter.
A	Alveolar.	CM	Cytomegalovirus.
a	arterial.	CMR	Cerebral metabolic rate.
A.V.	Atrio-ventricular.	CMRO ₂	Cerebral metabolic rate of oxygen.
A/C	Assist-controlled ventilation.	CMV	Controlled mechanical ventilation.
AADI	Anterior atlanto-dental interval.	CNS	Central nervous system.
Ab	Antibody.	CO	Cardiac output.
AB	Arterial blood.	CO ₂	Carbon dioxide.
ABG	Arterial blood gases.	CūO ₂	Mixed venous oxygen content.
ABP	Arterial blood pressure.	COPA	Cuffed oro-pharyngeal airway.
ACEIs	Angiotensin converting enzyme inhibitors.	COPD	Chronic obstruction pulmonary diseases.
Ach	Acetyl choline.	CP	Cardiopulmonary.
ACLS	Advanced cardiac life support.	CPAP	Continuous positive airway pressure.
ACT	Activated clotting time.	CPB	Cardiopulmonary bypass.
ACTH	Adreno-corticotrophic hormone.	CPK	Creatine phosphokinase.
AD	Autosomal dominant.	CPP	Cerebral perfusion pressure.
ADH	Antidiuretic hormone.	CPR	Cardiopulmonary resuscitation.
ADP	Adenosine di-phosphate.	CS	Caesarian section.
AEPs	Auditory evoked potentials.	CSA	Compressed spectral assay.
AF	Atrial fibrillation.	CSF	Cerebrospinal fluid.
Ag	Antigen.	CT	Computerized tomography.
AICD	Automatic implantable Cardioverter defibrillator.	CV	Cardiovascular, controlled ventilation, or central venous.
AIDs	Acquired immune-deficiency syndrome.	CVP	Central venous pressure.
ALI	Acute lung injury.	CVS	Cardiovascular system.
ALT	Alanine amino transferase.	D'O ₂	Oxygen delivery.
APCs	Atrial premature contractions.	D ₅ W	Dextrose 5% water.
APRV	Airway pressure release ventilation.	DBS	Double burst stimulation.
APUD	Amino precursor uptake and decarboxylation.	DDAVP	Desmopressin.
AR	Aortic regurgitation.	DIC	Disseminated intravascular coagulation.
AR	Autosomal recessive.	DIND	Delayed ischemic neurologic deficit.
ARDs	Acute respiratory distress syndrome.	dL	Deciliter.
AS	Aortic stenosis.	DLT	Double lumen endobronchial tube.
ASA	American Society of Anesthesiologists.	DLV	Differential lung ventilation.
ASD	Atrial septal defect.	DM	Diabetes mellitus.
AST	Aspartate amino transferase.	DPG	Di-phospho-glycerate.
ASV	Adaptive support ventilation.	DSA	Density Spectral Array.
ATC	Automatic tube compensation.	DVT	Deep venous thrombosis.
ATLS	Advanced trauma life support.	EC	Extracellular.
ATP	Adenosine tri-phosphate.	ECF	Extracellular fluid.
A-V	Arterio-venous.	ECG	Electrocardiogram.
AVP	Arginine vasopressin	ECMO	Extracorporeal membrane oxygenator.
BBB	Blood brain barrier.	ECT	Electro-convulsive therapy.
BEE	Basal energy expenditure.	ECV	Extracellular volume.
BiPAP	Biphasic positive airway pressure ventilation.	ED	Effective dose.
BIS	Bi-spectral index scale.	EDV	End diastolic volume.
BLS	Basic life support.	EDV	End diastolic volume.
BM	Bone marrow.	EEG	Electroencephalogram.
BMI	Body mass index.	EF	Ejection fraction.
BMR	Basal metabolic rate.	EMD	Electromechanical dissociation.
BP	Blood pressure.	EMG	Electromyography.
BT	Bleeding time.	EMI	Electromagnetic interference.
BUN	Blood urea nitrogen.	ENT	Ear, nose, and throat.
BW	Body weight.	EOMs	Extra-ocular muscles.
C and S	Culture and sensitivity.	EPO	Erythropoietin.
Ĉ	End pulmonary capillary.	ER	Emergency room.
C/P	Clinical picture.	ERV	Expiratory reserve volume.
Ca ⁺⁺	Calcium.	ESV	End systolic volume.
CABG	Coronary artery bypass grafting.	ESWL	Extracorporeal shock wave lithotripsy.
CAD	Coronary artery disease.	EtCO ₂ or ETCO ₂	End tidal carbon dioxide.
cAMP	Cyclic adenosine mono-phosphate.	ETT	Endotracheal tube.
CaO ₂	Arterial oxygen content.	F	Fahrenheit.
CARS	Counter anti-inflammatory response syndrome.	F ⁺⁺	Ferrous iron.
CAs	Catecholamines.	F ⁺⁺⁺	Ferric iron.
CAV	Cardiac allograft vasculopathy.	F ₄	Tetralogy of Fallot.
CBC	Complete blood picture.	FB	Foreign body.
CBF	Cerebral blood flow.	FDA	Food and drug administration.
CBV	Cerebral blood volume.	FDPs	Fibrin degradation products.
		FEV ₁	Forced expiratory volume in the first second.

IV

FF	Filtration fraction.	LVEDP	Left ventricular end diastolic pressure.
FFP	Fresh frozen plasma.	LVEDV	Left ventricular end diastolic volume.
FG	French gauge.	LVF	Left ventricular failure.
Fi	Inspiratory fraction.	LVSWI	Left ventricular stroke work index.
FRC	Functional residual capacity.	M	Molar.
FSH	Follicular stimulating hormone.	mA	Milliampere.
FVC	Forced vital capacity.	MAC	Minimal alveolar concentration.
G	Gauge.		Monitor anesthesia care.
G6PD	Glucose -6-phosphate dehydrogenase.	MAO	Membrane attack complex.
GA	General anesthesia.	MAOIs	Mono-amino oxidase.
GABA	Gamma amino butyric acid.	MAP	Mono-amino oxidase inhibitors.
GCS	Glasgow coma scale.	MARS	Mean arterial pressure.
GFR	Glomerular filtration rate.	MEN	Mixed antagonists response syndrome.
GH	Growth hormone.	MEPs	Multiple endocrine neoplasm.
GI	Gastro-intestinal.	mEq	Motor evoked potentials.
GIK	Glucose insulin potassium.	Mg	Milli-equivalent.
GIT	Gastro-intestinal tract.	mg	Magnesium.
gm	Gram.	MgSO ₄	Milligram.
GTN	Glyceryl trinitrate.	MHS	Magnesium sulfate.
H ⁺	Hydrogen.	MI	Malignant hyperthermia syndrome.
H ₂ O	Water.	MIDCAB	Myocardial infarction.
HAZMAT	Hazardous material.		Minimally invasive direct coronary artery bypass.
Hb	Hemoglobin.	min	Minute.
HBf	Hepatic blood flow.	mL	Millimeter.
HCO ₃	Bicarbonate.	mm	Millimeter.
Hct	Hematocrit.	mmHg	Millimeter mercury.
HF	Heart failure.	MMV	Mandatory minute ventilation.
HFFI	High frequency flow interrupters.	MODS	Multiple organ dysfunction syndrome.
HFJV	High frequency jet ventilation.	mosm	Milliosmole.
HFO	High frequency oscillation.	MR	Mitral regurgitation.
HFPV	High frequency positive pressure ventilation.	MRI	Magnetic Resonance imaging.
HFV	High frequency ventilation.	ms	Millisecond.
HIT	Heparin induced thrombocytopenia.	MS	Mitral stenosis.
HIV	Human immuno-deficiency virus.	MW	Molecular Weight.
HLAs	Human leukocyte antigens.	N ₂	Nitrogen.
HPV	Hypoxic pulmonary vasoconstriction.	N ₂ O	Nitrous oxide.
hr	Hour.	Na ⁺	Sodium.
HR	Heart rate.	NaHCO ₃	Sodium bicarbonate.
Hz	Hertz.	NIBP	Non-invasive blood pressure.
I.m.	Intramuscular.	NIDDM	Non-insulin dependant diabetes mellitus.
I.v.	Intravenous.	nm	Nanometer.
IABCP	Intra-aortic balloon counter pulsation.	NM	Neuromuscular.
IAP	Intra-abdominal pressure.	NMDA	N-methyl D-aspartate.
IC	Intracellular.	NMJ	Neuro-muscular junction.
ICF	Intracellular fluid.	NO	Nitric oxide.
ICP	Intracranial pressure.	NO ₂	Nitrogen dioxide.
ICT	Intracranial tension.	NPO	Nil per os.
ICU	Intensive care unit.	NREM	Non-rapid eye movement.
ID	Internal diameter.	NS	Normal saline.
IDDM	Insulin dependent diabetes mellitus.	NSAIDs	Non-steroidal anti-inflammatory drugs.
IFN	Interferon.	NYHA	New York Heart Association.
IFR	Inspiratory flow rate.	O ₂	Oxygen.
Igs	Immunoglobulins.	O ₂ ER	Oxygen extraction ratio.
IL	Interleukin.	OLV	One lung ventilation.
IMV	Intermittent mandatory ventilation.	OPCAB	Off pump coronary artery bypass.
INR	International normalized ratio.	OPP	Ocular perfusion pressure.
IOP	Intraocular pressure.	OR	Operative room.
IPPV	Intermittent positive pressure ventilation.	OSA	Obstructive sleep apnea.
IRV	Inspiratory reserve volume or inverse ratio ventilation.	OSH	Obstructive sleep hypopnea.
ITP	Idiopathic thrombocytopenic purpura.	P ⁺⁺	Phosphorus.
IU	International unit.	PA	Pulmonary artery.
IVC	Inferior vena cava.	PaCO ₂	Arterial partial pressure of Carbon dioxide.
IVOX	Intravenous oxygenation.	PACU	Post-anesthetic care unit.
j	Jugular.	PAD	Preoperative autologous donation.
K	Kelvin.	PADI	Posterior atlanto-dental interval.
K ⁺	Potassium.	PAF	Platelet activating factor.
Kg	Kilogram.	PAH	Para-amino hippuric acid.
Kpa	Kilopascal.	PaO ₂	Partial pressure of oxygen.
L	Liter.	PaO ₂	Arterial partial pressure of O ₂ .
LA	Local anesthesia.	PAP	Pulmonary artery pressure.
LAD	Left anterior descending.	PAV	Proportional assist ventilation.
LAP	Left atrial pressure.	PCA	Patient controlled analgesia.
Las	Local anesthetics.	PcO ₂	Conjunctival O ₂ tension.
LBBB	Left bundle branch block.	PcCO ₂	Mixed venous partial pressure of CO ₂ .
LEC	Lower esophageal contractility.	PCWP	Pulmonary capillary wedge pressure.
LH	Leutenizing hormone.	PDA	Patent ductus arteriosus.
LIP	Lower inflection point.	PDPH	Post-dural puncture headache.
LMA	Laryngeal mask airway.	PE	Pre-eclampsia.
LMWH	Low molecular weight heparin.	PEA	Pulseless electrical activity.
LR	Lactate ringier.	PEEP	Positive end expiratory pressure.
LV	Left ventricle or left ventricular.		

V

PEFR	Peak inspiratory flow rate.	SVC	Superior vena cava.
PFC	Perfluorocarbons.	SVI	Stroke volume index.
PFO	Patent foramen ovale.	SVP	Saturated vapor pressure.
PFTs	Pulmonary function tests.	SVR	Systemic vascular resistance.
PGs	Prostaglandins.	SVT	Supraventricular tachycardia.
PIFR	Peak inspiratory flow rate.	SWMA	Segmental wall motion abnormalities.
PIH	Pregnancy induced hypertension.	T _{1/2}	Half life.
PIP	Peak inspiratory pressure.	TB	Tuberculosis.
PONV	Postoperative nausea and vomiting.	TBSA	Total body surface area.
ppm	part per million.	TBW	Total body water.
PPN	Peripheral parenteral nutrition.	TCD	Trans-cranial Doppler.
PR	Pulmonary regurgitation.	TEE	Trans-esophageal echocardiography.
PRVC	Pressure regulated volume control.	TEG	Thromboelastography.
PS	Pulmonary stenosis.	TGA	Transposition of great arteries.
PSV	Pressure support ventilation.	TGI	Tracheal gas insufflation.
PSVT	Paroxysmal supraventricular tachycardia.	TIAs	Transient ischemic attacks.
PT	Prothrombin time.	TIVA	Total intravenous anesthesia.
PTCA	Percutaneous trans-luminal coronary angioplasty.	TLC	Total lung capacity.
		TNF	Tumor necrosing factor.
PtcCO ₂	Transcutaneous CO ₂ tension.	TOF	Train of four.
PtcO ₂	Transcutaneous O ₂ tension.	TPIS	Trans-jugular intra-hepatic porto-systemic shunt.
PTH	Parathyroid hormone.		
PTT	Partial thromboplastin time.	TPN	Total parenteral nutrition.
PVC	Packed cell volume or pressure controlled ventilation.	TR	Tricuspid regurgitation.
		TRALI	Transfusion related acute lung injury.
PVC	Polyvinyl chloride.	TS	Tricuspid stenosis.
PVCs	Premature ventricular contractions.	TSH	Thyroid stimulating hormone.
PVR	Pulmonary vascular resistance.	TURP	Trans-urethral resection prostate.
Qs	Venous admixture.	TV	Tidal volume.
Qt	Total cardiac output.	TxA ₂	Thromboxane A ₂ .
RA	Right atrium.	U/S	Ultrasound.
RAP	Right atrial pressure.	UB	Urinary bladder.
RBBB	Right bundle branch block.	UBF	Utero-placental Blood flow.
RBC or RBCs	Red blood cells.	UIP	Upper inflection point.
RBF	Renal blood flow.	UK	United kingdom.
RCA	Right coronary artery.	UOP	Urine output.
rCBF	Regional cerebral blood flow.	UROD	Ultrarapid opioid detoxification.
RDS	Respiratory distress syndrome.	URTI	Upper respiratory tract infection.
REE	Resting energy expenditure.	USA	United State of America or unilateral spinal anesthesia.
REM	Rapid eye movement.		
RES	reticulo-endothelial system.	UUN	Urinary urea nitrogen.
RF	Renal failure.	v	Venous.
ROP	Retinopathy of prematurity.	V	Ventilation.
RPF	Renal plasma flow.	V/Q or V/P	Ventilation/perfusion.
RR	Respiratory rate.	V'O ₂	Oxygen uptake.
RV	Right ventricle or residual volume.	VAD	Ventricle assist device.
RVF	Right ventricular failure.	VAE	Venous air embolism.
RVSWI	Right ventricular stroke work index.	VAPS	Volume assured pressure support.
SA	Sino-atrial.	VAT	Video-assisted thoracoscopy.
SaO ₂	Saturation of Oxygen in the arterial blood.	VC	Vasoconstriction or Vital capacity.
SC	Subcutaneous.	Vd	Dead space.
SD	Standard deviation.	VD	Vasodilatation.
Sec	Second.	VF	Ventricular fibrillation.
SGOT	Serum glutamic oxalo-acetic transaminase.	VF	Ventricular fibrillation.
SGPT	Serum glutamic pyruvate transaminase.	VLDL	Very low density lipoprotein.
SI	Systemic international.	VM	Vasomotor.
SIMV	Synchronized intermittent mandatory ventilation.	VR	Venous return.
		VS	Volume support.
SIRS	Systemic inflammatory response syndrome.	VSD	Ventricular septal defect.
SjO ₂	Jugular venous blood oxygen saturation.	Vt	Tidal volume.
SLE	Systemic lupus erythematosus.	VT	Ventricular tachycardia.
SLEC	Spontaneous lower esophageal contractility.	VWF	Von Willebrand factor.
SNP	Sodium nitroprusside.	WAD	Weapons of mass destruction.
SuO ₂	Mixed venous Oxygen saturation.	WBCs	White blood cells.
SpO ₂	Saturation of Oxygen in the arterial blood.	WEB	Wire-guided endobronchial blockers.
SSA	Selective spinal anesthesia.	WPW	Wolf Parkinson White.
SSEPs	Somato-sensory evoked potentials.	XL	Six linked.
SV	Stroke volume.		

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Spotlights on
Anesthesia



HESHAM M EL-AZZAZI